DIANA
Finite Element Analysis

User's Manual

Getting Started

Release 9.3

TNO DIANA BV

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DIANA – Finite Element Analysis
User's Manual release 9.3
Getting Started

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Preface

This volume of the DIANA User's Manual introduces the novice user to the DIANA Finite Element Analysis code. Moreover it formally describes things like convention of notation in the User's Manual, how to run an analysis job etc.

Novice user's are advised to read the chapters of this volume sequentially with DIANA at hand, installed on a familiar computer system. Doing so will give a general insight in the capabilities and user interfaces of DIANA, a basis for more specific subjects in other volumes. The User's Manual for the DIANA-9.3 release comprises the following volumes.

Getting Started (this volume), gives a general overview of various aspects of the DIANA finite element code. Introduces the DIANA batch interface and the ¡DIANA interactive graphics interface to the novice user.

Analysis Procedures**,** describes the various analysis procedures. Specifies the appropriate input data and user commands for the DIANA batch interface.

Element Library**,** describes the various finite elements. Specifies the appropriate input data like connectivity and loading for the DIANA batch interface.

Material Library**,** describes the various material models. Specifies the appropriate input data for the DIANA batch interface.

Pre- and Postprocessing**,** the reference manual for the ¡DIANA interactive graphics interface.

FX+ for DIANA**,** is a tutorial introduction to the combined use of the FX^+ pre- and postprocessor and DIANA.

Analysis Examples**,** presents examples of various types of finite element analysis, performed on a wide range of finite element models. Includes tutorial examples of the ¡DIANA Pre- and Postprocessing interactive graphics interface.

Concrete and Masonry Analysis**,** describes and illustrates the application of DIANA for analysis of concrete and masonry models.

***Geotechnical Analysis*,** describes and illustrates the application of DIANA for geotechnical analysis like 'Soil–Pore Fluid Analysis' and 'Liquefaction Analysis'.

***Application Modules*,** describes and illustrates the DIANA modules for special applications like 'Parameter Estimation' and 'Lattice Analysis'.

***Cumulative Index*,** very helpful if you don't know where to search in the User's Manual for a particular subject.

Cautionary note. Throughout this manual, it will be assumed that the reader has a basic understanding of applied mechanics and the Finite Element Method in general.[1] Also some experience with use of computers and computer programs is assumed.

[1] Very informative introductions are the "Guidelines to Finite Element Practice" [10] and the book "A Finite Element Primer" [11], both published by NAFEMS.

Chapter 1

General Introduction

DIANA is a general purpose finite element code, based on the Displacement Method.[1] It has been under development at TNO since 1972. In the beginning of 2003 a new organisation around DIANA was founded: TNO DIANA bv. This chapter is a general introduction to the use of the DIANA Finite Element Code. The first section gives a short overview of the field of application [§ 1.1]. The second section introduces DIANA's program structure and the various user interfaces [§ 1.2].

1.1 Field of Application

DIANA is a multi-purpose finite element program (three-dimensional and nonlinear) with extensive material, element and procedure libraries based on advanced database techniques. Developed by civil engineers from a civil engineering perspective, DIANA's most appealing capabilities are in the fields of concrete and soil. Worldwide, engineering consultants apply DIANA to their work on bridge design, dams, offshore platforms, road and rail design, and tunneling. After the Kobe earthquake, many Japanese DIANA users turned their attention to DIANA's power in dynamic loading analysis as well. Furthermore, DIANA is extensively used for research and analysis purposes at technical universities on every continent.

1.1.1 Capabilities

Civil, mechanical, biomechanical, and other engineering problems can be solved with the DIANA program. Standard DIANA application work includes: concrete cracking, excavations, tunneling, composites, plasticity, creep, cooling of concrete, engineering plastics, various rubbers, groundwater flow, fluid–structure

[1] DIANA = DIsplacement method ANAlyser.

interactions, temperature-dependent material behavior, heat conduction, stability analysis, buckling, phased analysis, et cetera.

DIANA offers a great variety of elements (see Appendix C), such as beams (straight and curved), solids, membranes, axisymmetric and plane strain elements, plates, shells, springs, and interface elements (gap). All these elements may be combined in a particular finite element model. Moreover, special elements may be used to model embedded reinforcement in concrete structures: bars, grids and prestressed cables. To model these reinforcements DIANA has a built-in preprocessor in which reinforcement can be defined globally. Volume *Element Library* gives a complete overview of the available element types.

DIANA offers a variety of advantages over other commercially available FEM software. One of the most notable benefits is its power in the field of concrete and soil where excellent material models are available, developed by researchers in the Netherlands since the early 1970's. Most notably are the models for smeared and discrete cracking, and for reduction of prestress due to special effects. DIANA also offers unique analysis capabilities in Parameter Estimation and Lattice analysis. In addition, DIANA can do various types of dynamic analysis important in earthquake engineering.

1.1.2 Analysis Types

With DIANA you can choose from a wide range of analysis types, all extensively described in Volume *Analysis Procedures*. Here we give a short overview.

Linear static analysis. The Linear Static module provides a solid base for the DIANA finite element program. We mention some of the most important features. Linear constraints (tyings) can be specified to model linear dependencies between degrees of freedom of the system of equations (displacements, rotations, temperatures etc.). Moving loads can be applied to determine influence lines and fields for critical result items. Fatigue failure analysis can be performed using standard Wöhler diagrams.

Nonlinear analysis. DIANA's strongest points lie in its nonlinear capabilities. For physical nonlinear analysis various material models are available including plasticity, viscoplasticity, cracking, viscoelasticity, creep, hyperelasticity, liquefaction of soil and many more [§ 1.1.3]. Time dependent development of temperature, concentration and maturity can be specified.

For geometrical nonlinear analysis the Total and Updated Lagrange methods are available Moreover, contact analysis can be performed to check whether contact occurs in user-specified possible contact zones in the model.

Dynamic analysis. All appropriate types of dynamic structural analysis may be performed with DIANA: steady-state harmonic modal and direct frequency response analysis, spectral response analysis, hybrid frequency time domain

analysis, linear and nonlinear transient analysis, and fluid–structure interaction analysis.

Euler stability analysis. Euler stability analysis gives information about 'linearized stability' of a structure and provides a relatively simple and effective method to get a fair impression of a structure's buckling modes. The Euler stability analysis may be followed by a perturbation analysis to investigate the postbuckling behavior. The postbuckling displacement field is solved by applying a continuation analysis using a stepwise generalized Newton–Raphson scheme.

Potential flow analysis. A potential flow analysis may be employed to solve general one-potential convection–diffusion problems. It can be used in the following application fields: heat flow, detailed and regional groundwater flow, beam cross-section analysis, fluid–structure interaction, and Reynolds flow or lubrication. The heat flow module includes special features to perform advanced potential flow analysis. For instance, hydration heat and cooling pipe elements can be used to study the thermal behavior of cement-based materials at early ages. The solidification and evaporation process within a liquid can also be modeled. Groundwater flow analysis also benefits from advanced features such as the modeling of seepage faces or study of the contamination transport of a pollutant within a soil.

Coupled flow–stress analysis. In coupled flow–stress analysis the interaction may be two- or one-directional. You may use a mixture analysis with mixture elements for two-directional interaction problems, for example a geotechnical transient consolidation analysis. A staggered analysis can be performed to solve one-directional interaction problems like geotechnical (static) stability analysis or structural analysis with thermal load.

Phased analysis. DIANA enables modeling of phased construction. It determines the effects of construction history and shows the critical construction stages. Phased analysis can be performed on a structural level and on a potential flow level.

Parameter estimation. Parameter estimation may be used to determine non-shape parameters by minimizing the differences between calculated and target displacements. The confrontation of target displacement field data with calculated field data leads to a quantitative determination of the unknown parameters. The parameters may comprise material properties, geometric properties (like the thickness of a plate), and load factors within combinations of load cases.

Lattice analysis. DIANA offers a special module for analysis with the Delft lattice model. This is a discrete material model where the continuum is replaced by an equivalent beam or truss structure, the lattice. The main purpose of the lattice model is to achieve understanding of the fracture processes which occur at small scales and the influence of the micro-structural disorder on the global behavior of the material.

1.1.3 Material Models

DIANA offers a wide variety of material models which can be applied in the various analysis types. All material models are extensively described in Volume *Material Library*. As an introduction, we present a summary of the most important models.

Elasticity. For linear structural analysis the simple iso- and orthotropic elasticity models are available. Within nonlinear analysis there are three applications for an elastic material model: ambient influence (temperature, concentration, maturity and time), nonlinear elasticity to set a unique nonlinear relation between stress and strain, and modified elasticity which modifies the elasticity parameters during the analysis.

Nonlinear elasticity is typically applied for granular materials, for which DIANA offers two models: the standard Grains model and the model according to Boyce for granular materials under repeated loading. Modified elasticity is particularly relevant for soil mechanics, for instance to modify Poisson's ratio and Young's modulus after having set the long term (drained) initial soil stresses.

For rubbery materials, DIANA offers hyperelasticity models which can handle large strains and large deformations. The Mooney–Rivlin, and Besseling models are available to define the deviatoric part of the strain energy function. The hydrostatic part may be described with an incompressibility model, or with a linear or nonlinear compressibility model.

In the material library the regular models for plasticity are available: Tresca, Von Mises, Mohr–Coulomb, and Drucker–Prager. To handle combined tension and compression for concrete plasticity, DIANA offers the Rankine principal stress model, stand-alone or in combination with Von Mises or Drucker–Prager.

For clay-like materials there is the Egg Cam-clay model and for sand-like materials the Modified Mohr–Coulomb model. For orthotropic plasticity the models of Hill and Hoffmann are available. For rock-like materials the model of Hoek–Brown as available. To incorporate viscous effects in plastic behavior, DIANA offers the viscoplastic models of Perzyna and Duvaut–Lions.

Another plasticity special is the Fraction model which may be used for plasticity and metal creep analyses. It splits the material into a number of fractions, each of them having its own plasticity and creep parameters.

Cracking. Various so-called smeared cracking models are available to simulate cracking of brittle materials like concrete. Basically these models are

a combination of tension cut-off, tension softening and shear retention criteria. A rate-dependent cracking criterion can be added optionally. The smeared cracking models can also be specified with ambient influence, i.e., dependent of temperature, concentration or maturity.

In addition to the smeared cracking models, two constitutive models based on total strain are available: the fixed and the strain rotating concept. These models describe the cracking and crushing behavior of the material with a nonlinear elasticity relationship. The total strain models are very well suited for Serviceability Limit State (SLS) and Ultimate Limit State (ULS) analyses.

Viscoelasticity. Viscoelasticity can be applied via a Maxwell Chain model for the relaxation function and a Kelvin Chain model or the Double Power law for the creep function. Built-in creep models are available for some model codes for concrete: the European CEB-FIP model code 1990, the Dutch NEN 6720 code and the American ACI code 209.

Soil specials. Especially for nonlinear soil mechanics you may specify the initial stress ratio. Moreover, the undrained behavior can be specified via the excess pore fluid pressure.

Three dedicated constitutive models are available to analyze the liquefaction of soil subjected to seismic loading: the Towhata-Iai model for two-dimensional undrained analysis, the Bowl model for partly drained conditions with predominantly horizontal shearing, and the Nishi model for partly drained conditions with an arbitrary shearing direction.

Interface nonlinearities. For interface elements, you may specify a nonlinear relation between tractions (stresses) and relative displacements across the interface. To simulate the interface behavior, various models are available: discrete cracking, crack dilatancy, bond-slip, friction, nonlinear elasticity, and a general user-supplied interface model.

User-supplied material model. On top of all the built-in material models, DIANA offers the user-supplied subroutine mechanism to let you specify a general nonlinear material behavior.

1.1.4 Solvers

DIANA offers various solution procedures which are needed to solve the system of equations of a finite element model. For a complete description see Volume *Analysis Procedures*.

Linear equations. DIANA can solve the linear system of equations either direct or iteratively. Two direct methods are available: a Sparse Cholesky decomposition method, and an out-of-core Gauss decomposition method. On

Intel based Windows and Linux platforms a third method is available: the Intel PARDISO solution method, i.e. a parallel direct sparse solver. The Sparse Cholesky method is the default and will do in most cases. By default both direct solution methods are applied in combination with an automatic optimal ordering procedure.

An iterative method is available to solve the linear system of equations. The preconditioning process can be customized: you may specify the parameters for two types of preconditioning: Incomplete LU-decomposition or Diagonal.

Nonlinear equations. In a nonlinear analysis, the nonlinear system of equations must be solved iteratively until equilibrium has been reached. Therefore DIANA offers the well-known iteration schemes: Constant and Linear Stiffness, Regular and Modified Newton–Raphson. Moreover three Quasi-Newton methods are available: Broyden, BFGS, and Crisfield.

All iteration schemes may be combined with Arc-length control methods to adapt the loading during iterations in one load step, you may choose the the Spherical Path or the Updated Normal Plane method. An Indirect Displacement control option is available to cope with problems like snap-through and snap-back behavior. To stabilize the convergence or increase its speed, a Line Search algorithm may be applied.

Eigenvalues. Depending in the type of element matrices to be applied, an eigenvalue analysis with DIANA may be performed to get the free vibration frequencies and eigenmodes, to solve the standard eigenproblem, or for linearized buckling analysis.

1.2 Program Structure

The architecture of the DIANA system, as seen from the user's point of view consists of a number of *modules*, indicated with *M1* to *Mn* in Figure 1.1. Each module fulfills a clearly defined task in the Finite Element Analysis. For instance, Module INPUT (*M1*) reads the description of the finite element model. All modules have data communication with a central database, the FILOS file. After the analysis DIANA can produce output of the analysis results.

To have access to this software architecture, there are three basic user-interfaces: a *batch interface*, an *interactive graphical* interface (GUI), and an interface with *user-supplied subroutines*.

1.2.1 Batch Interface

The dashed lines in Figure 1.1 indicate the batch interface to DIANA. In the batch interface the user defines the finite element model via an input data file. Furthermore, analysis commands must be supplied to indicate how the analysis should be performed. DIANA will then load the appropriate modules to perform

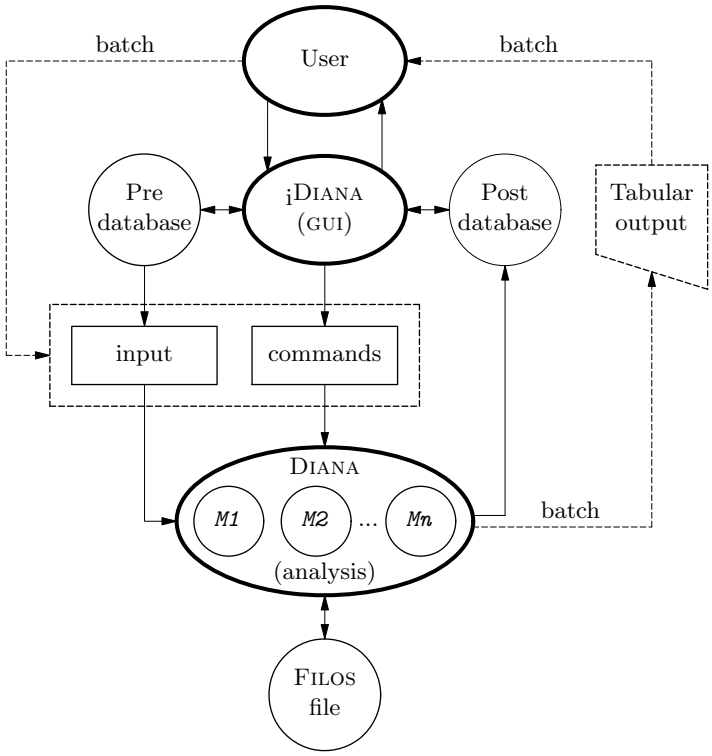


Figure 1.1: DIANA program architecture

the analysis. Output can be obtained in tabular form for printing or viewing. See Chapter 3 for a comprehensive introduction to DIANA's batch interface.

1.2.2 Graphical User Interface

The interactive graphics interface, called ¡DIANA, is a fully integrated pre- and postprocessing environment to DIANA [Fig. 1.1]. With ¡DIANA you specify the basic model geometry, loading, materials and other data interactively. This data is stored in a database for preprocessing from which ¡DIANA can automatically generate the finite element model in the form of the input data file. Moreover, the necessary analysis commands may be generated via user-friendly interactive forms. Analysis results are written to a database for interactive postprocessing and may then be presented in various styles like colored contour plots, diagrams, tables etc. See Chapter 2 for an introduction to DIANA's interactive Graphical User Interface.

1.2.3 User-supplied Subroutines

DIANA offers a user-supplied subroutine option to the advanced user, with skill in programming. Via this option the code of various subroutines with predefined arguments may be supplied to define special material models, interface behavior and the like.

Chapter 2

Graphical User Interface

This chapter introduces the interactive graphical user interface to the DIANA finite element analysis capabilities, also known as ¡DIANA.[1] First we will outline how to start up ¡DIANA and introduce its basic look-and-feel [§ 2.2]. Then we will demonstrate how to build a finite element model in the Design environment [§ 2.3]. To perform the actual finite element analysis of the model ¡DIANA offers an interactive interface to the batch analysis commands which we will briefly demonstrate [§ 2.4]. Then we will show some basic features of the Results environment where we may display the analysis results in various styles [§ 2.5]. Finally we will show how to leave ¡DIANA [§ 2.6].

2.1 Model of a Hexagonal Plate

As an introduction to ¡DIANA we will demonstrate the linear elastic analysis of a plate as shown in Figure 2.1 on the following page. The outer edge of the plate is a regular hexagon with corners on a circle with radius $r_o = 10$ m. Concentric with the outer edge, the plate has a circular hole with a radius $r_i = 4$ m. The plate is vertically supported ($u_Z = 0$) at each of the corners along the outer edge.

Properties. We assume that the plate is made of concrete with a Young's modulus $E = 22000$ MPa, a Poisson's ratio $\nu = 0.2$, and a mass density $\rho = 2400$ kg/m^3. The thickness of the plate is $t = 0.30$ m. The loading consists of the dead weight and of a vertical load $q_Z = -20$ kN/m uniformly distributed along the edge of the circular hole.

Finite element model. Due to symmetry of the geometry, the supports and the loading it is sufficient to model and analyze only one quarter of the plate,

[1] For a formal reference of ¡DIANA's facilities see Volume *Pre- and Postprocessing*.

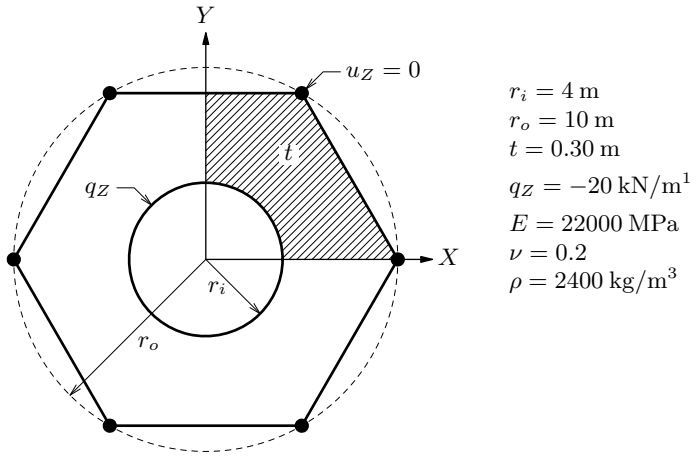


Figure 2.1: Model of hexagonal plate

provided that we impose appropriate boundary conditions along the symmetry lines. Furthermore we may choose regular plate bending elements because there is neither in-plane loading nor in-plane deformation, otherwise shell elements would have been required. In this case we will apply eight-node quadrilateral CQ24P elements.[2]

2.2 Starting iDIANA

If ¡DIANA has been installed properly on your computer, you may start an interactive session by typing `idiana` or by clicking the appropriate icon on the desktop.[3]

2.2.1 The Initial Working Window

Initially ¡DIANA brings you in the Index working environment where the various models are recorded. In this environment you have to tell ¡DIANA whether you are going to build a model in the Design environment or to examine the analysis results of a model in the Results environment. In this example we start with building a new model like outlined in the next section. In the window of the Index environment you may recognize various areas, also called *widgets*, and opportunities to manipulate these [Fig. 2.2]. The large gray square is the

[2] See Appendix C for an overview of DIANA element types and Volume *Element Library* for comprehensive description.

[3] The illustrations in this chapter, and in all other example descriptions in the DIANA User's Manual, only serve as signs of recognition. For a good understanding of the discussions we suggest that you perform the commands in a real-life interactive ¡DIANA session.

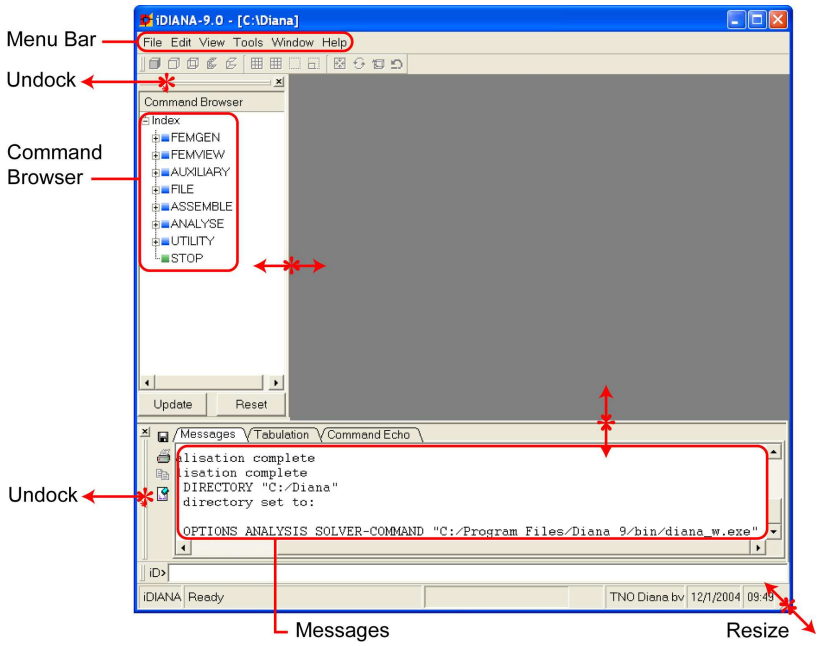


Figure 2.2: Interactive working window

location for the *Graphics Window* where pictures of the model are displayed. The Graphics Window becomes active as soon as you have opened a Finite Element Model [§ 2.3].

Basically you communicate with ¡DIANA via menu's in the Menu Bar and via commands in the Command Browser tree view control. Any messages that ¡DIANA would give appear in the Tabular Output widget below. You can resize the working window by dragging its edges or corners. Some of the widgets can be resized individually by dragging their edges. By default, all widgets are docked inside the working window. You can move around, or even undock, some of the widgets by dragging their docking handles, i.e., the double line at the left side. To redock a widget you must double click its title bar.

2.3 Designing a Model

The process of the definition of a new model typically involves tasks as initiation, definition of geometry and boundary conditions and more. We will now discuss this definition, also known as preprocessing, and simultaneously introduce the basics of the ¡DIANA Graphical User Interface.

2.3.1 Initiating a New Model

To initiate a new model you must take the following steps [Fig. 2.3].

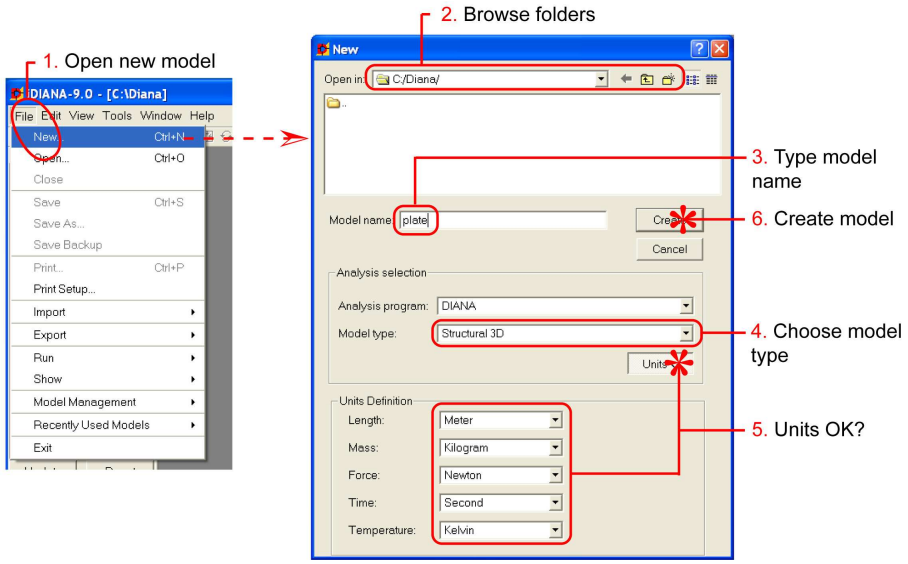


Figure 2.3: Initiating a new model

(1) Choose File → New from the Menu Bar. A dialog New now pops up where you can specify some parameters to identify the new model.

(2) Use the file browser on top of the dialog to define, and/or move to, the folder where you want to keep all the data of the new model, also known as the 'working directory'. In this case we choose C:/Diana.

(3) Type the name of a new model. You may type either lower or upper case letters but ¡DIANA will not consider the case of the text as significant. In this case we choose the name PLATE.

(4) Specify the type of analysis for which the new model is intended. ¡DIANA will apply the type to adapt lists, menus and dialogs in the graphical user interface to contain only the appropriate element types and properties

The list box shows the possible types. For this example you must choose Structural 3D which indicates a model for a three-dimensional structural analysis. Why three-dimensional? In this model of a bending plate, the geometry is two-dimensional but the loading and displacement occurs in the third dimension. Therefore the model is characterized as three-dimensional.

(5) Click the Units button to open the Units Definition field. Here you may check or indicate the units in which the model data will be specified. By default DIANA assumes SI-units which is OK for this example. Note the NONE unit for 'force', because specification of units for both 'mass' and 'force' is ambiguous.

(6) Finally click the Create button to start the creation of the new model. The New dialog disappears and the working window adapts its layout for the Design environment.

2.3.2 The Working Window

Compared to the Index environment [Fig. 2.2], the working window in the Design environment shows some additional widgets [Fig. 2.4].

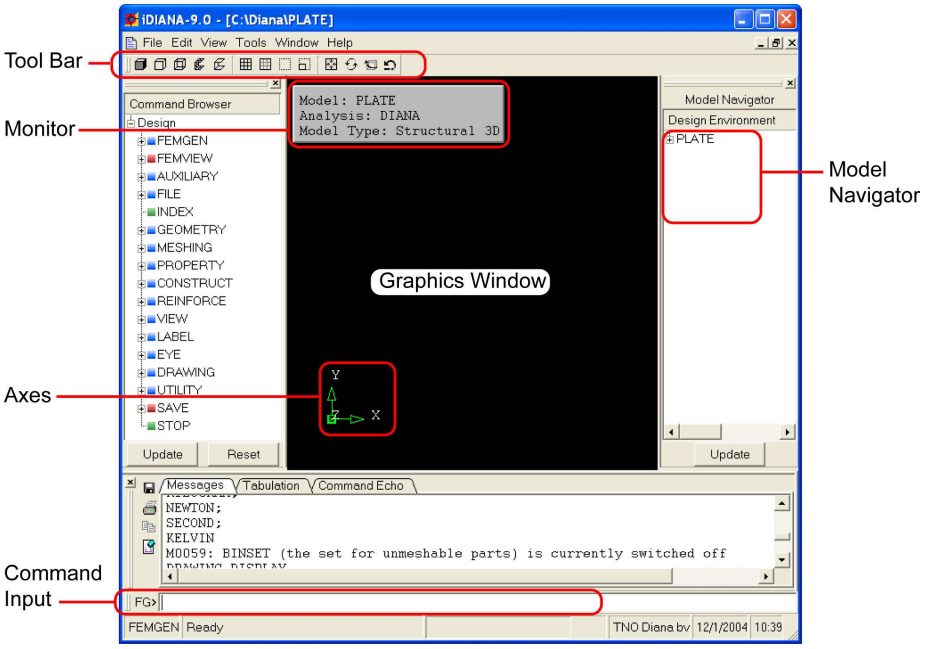


Figure 2.4: Working window in the Design environment

Graphics Window. Most notably is the black square in the center: the Graphics Window. Here ¡DIANA will display the model and some basic information. Initially it comprises the Monitor and the display of Axes. The Monitor shows the name of the current model: 'Model: PLATE'. The text 'Analysis: DIANA' indicates that the preprocessing concerns a model to be analyzed by DIANA. This involves the assignment of DIANA elements to generic elements of ¡DIANA

according to the chosen model type. For a new model, the Graphics Window initially shows an XYZ coordinate axis system with the X and Y model axes respectively horizontally and vertically in the viewing plane.

As the ¡DIANA Graphical User Interface is based on the OpenGL standard [12] you can interactively manipulate the model. Press and hold down the CTRL key and then drag the mouse cursor while holding one of the mouse buttons down:

Left – to rotate the model.

Middle – to zoom in and out.

Right – to translate the model in the Graphics Window.

Command Browser. The Command Browser now shows the top-level commands appropriate for the Design environment. The colored squares in front of a keyword indicate its status in the command. A blue square ■ marks a keyword with a mandatory submenu. A red square ■ marks a keyword with an optional submenu. A green square ■ marks a keyword which is the end of a command.

Command Input. Any command that you give via the Command Browser will be displayed in the Command Input line. The command prompt **FG>** indicates that you are in the Design environment. You may also type a command directly in the Command Input and then press the ENTER key to submit it to ¡DIANA for processing.

Tool Bar. The Tool Bar becomes enabled with tool buttons as a short-cut for some commands, particularly to manipulate the picture. If you leave the cursor on the button for a while, without clicking, the button's meaning will show up.

2.3.3 Geometry Definition

We will now discuss the building of the model for the example of Figure 2.1 on page 10. The first thing to do is define the geometry of the model via so-called geometric parts: points, lines, surfaces, and bodies. Typically, points are defined by their coordinates, lines by their end points, surfaces by their bounding lines, and bodies by their bounding surfaces. For the plate in this example we will not apply bodies because there are no solid elements. The points in the geometry of this model are the vertices along the outline of the quarter plate. Naturally we could compute their coordinates and directly input them. However, it is more convenient to let ¡DIANA determine the points from the basic dimensions of this plate: the radii of the inner and circumscribed circles.

Definition of a point. You can define a point by performing the following actions [Fig. 2.5].

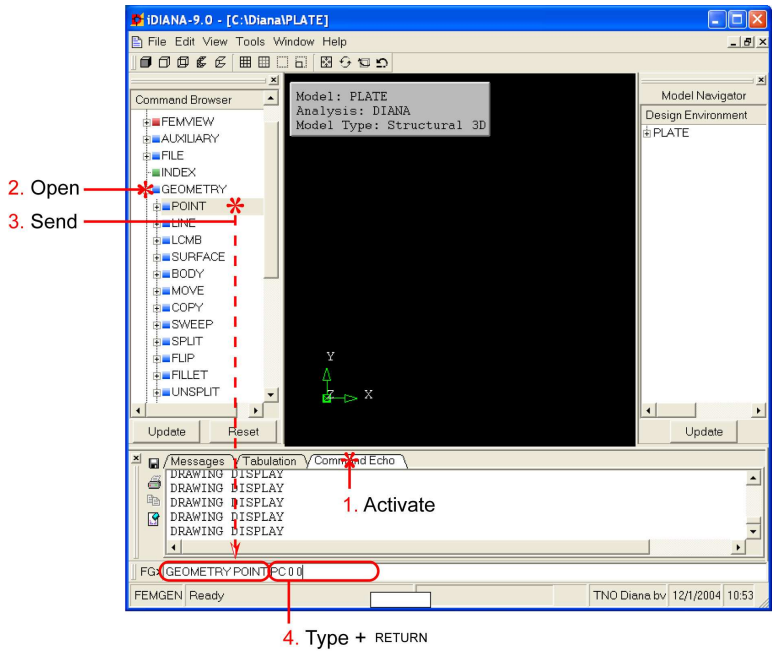


Figure 2.5: Issuing a command to define a point

(1) Click the Command Echo tab to activate the echoing of commands that you are about to issue. This it not strictly necessary, however it is very convenient to see the commands being echoed when ¡DIANA executes them.

(2) The basic command to define any geometric part is GEOMETRY. When you click the ⊞ in front of the GEOMETRY keyword in the Command Browser the command tree opens itself. The open branch shows the keywords of the options for the GEOMETRY command. These keywords define various geometric parts, for instance POINT to define a point, and LINE to define a line.

(3) Click the POINT keyword to indicate that you are going to define a point. The command now appears on the command line.

Alternatively to steps 2 and 3 you may type the command directly on the command line. To simplify the typing of commands you may abbreviate them. ¡DIANA only requires that you type as many characters needed to prevent ambiguity. In this case it would have been sufficient to type G P instead of GEOMETRY POINT.[4] Direct typing of abbreviated commands is particularly useful if you are an experienced user.

[4]The DIANA User's Manual always shows the complete command.

(4) Now you may complete the command to define the center of the plate. Type a name PC and coordinates 0 0 and then press the RETURN key. This defines a point called PC located at the origin of the coordinate system: $X = 0$, $Y = 0$, $Z = 0$. ¡DIANA assumes the omitted Z coordinate to be zero.

Note that the decimal point in specified numerical values is optional. Large values may be specified in scientific format, for instance 2.25E4 for a value of 22500.

¡DIANA confirms that the point PC has indeed been created [Fig. 2.6].

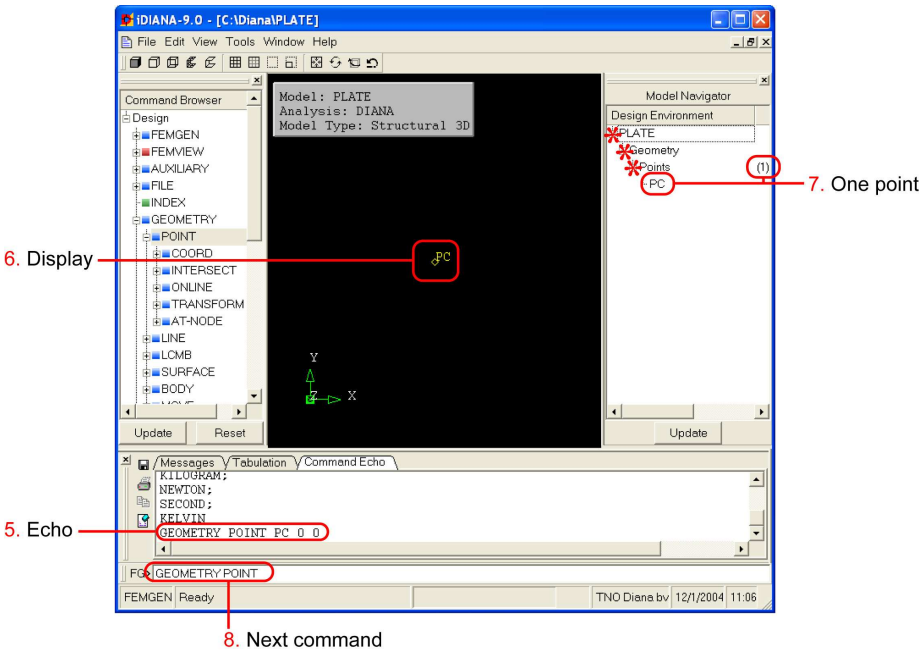


Figure 2.6: Echoing a defined point

(5) The command is echoed in the Command Echo tab.

(6) The point is displayed in the Graphics Window: a small square with a name label, both in yellow.

(7) When you open the tree in the Model Navigator by clicking the ⊞ markers in front of PLATE, Geometry and Points, ¡DIANA shows the number of currently defined points in parentheses and also a list of their names. In this case we see (1) and PC which indicates that the model comprises only one point.

(8) You will notice that ¡DIANA refills the command line with the same command, but without coordinates. This is to make the definition of additional points easier. To erase this preset command you may press the ESCAPE key on the keyboard. This key also serves as a general eraser when you make typing mistakes.

Intermezzo. Until now we have shown commands as part of screen-dumps. This is a rather inefficient way with respect to readability, book printing etc. Therefore, from now on commands will be presented in normal typographic style, with a sans serif upper case type font. The User's Manual displays the commands that we have discussed until now as follows.

plate.fgc

```
FEMGEN PLATE
STRUCT_3D
METER
KILOGRAM
NONE
SECOND
KELVIN
GEOMETRY POINT PC 0. 0.
```

Note that the FEMGEN PLATE command is an alternative to the File → New menu option. The indication `plate.fgc` on top of the command display refers to the name of the file with commands for preprocessing of this model. This file is part of the DIANA distribution, so you can use it to run the preprocessing of this example in a batch job [§ 2.3.9 p. 30].

Defining lines. After having erased the preset command on the command line you may give GEOMETRY LINE commands to define two circles.

plate.fgc

```
GEOMETRY LINE CIRCLE PC 4
GEOMETRY LINE CIRCLE PC 10
EYE FRAME
```

The CIRCLE option indicates that the line is a full circle. In this case we define the circle by its center point PC and its radius.

Adjusting the view. Whenever you define a new geometric part, ¡DIANA will display it in the Graphics Window at its proper location. By default the viewport on the Graphics Window is a 1×1 square, with its lower-left point at the origin of the coordinate system. Therefore initially you don't see the defined circles on the screen. By means of the EYE FRAME command you ask ¡DIANA to change the viewport such that the currently defined geometry will fit in it comfortably [Fig. 2.7].

At first you will notice that the Monitor slightly overlaps the display of the geometry. As the monitor has become a bit superfluous – it does not change during the design process – we may remove it via the command

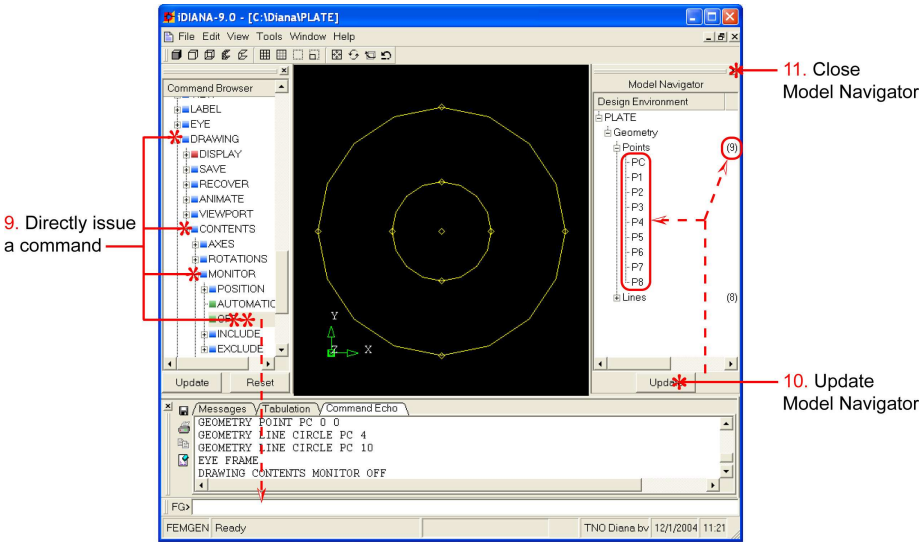


Figure 2.7: Adjusting the view

plate.fgc

```
DRAWING CONTENTS MONITOR OFF
```

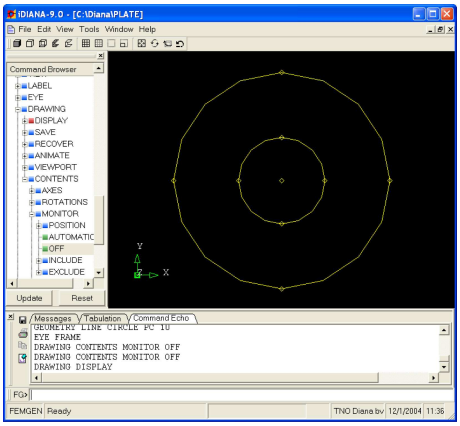
We will demonstrate how to issue this command directly via the Command Browser.

(9) Open the full command by clicking on the ⊞ signs in the command tree. In the final branch under MONITOR a green square ■ precedes the OFF keyword. This means that the keyword terminates a command. You may directly issue the command by *double-clicking* on the OFF keyword. The complete command flickers in the Command Input line and is executed immediately (note its echo in the Command Echo tab). The monitor has now disappeared [Fig. 2.7].

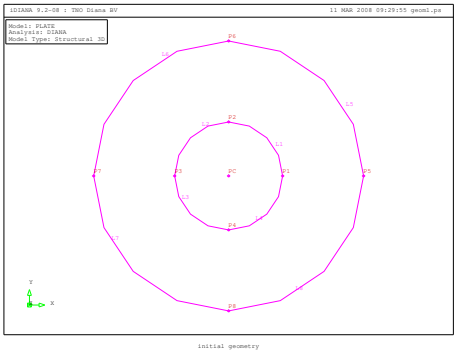
There are a few more topics which adjust the display.

(10) Click the Update button to get an updated view of the Model Navigator. In this case we see that the model now comprises nine points and eight lines.

(11) To get a larger Graphics Window we may get rid of the Model Navigator. Click the close button ☒ in its upper-right corner. You can get the Model Navigator back whenever you want via the View → Model Navigator menu entry.



(a) screen display



(b) from plot file

Figure 2.8: Initial geometry

What is being displayed? The working window now shows a viewport with two large yellow circles [Fig. 2.8a]. The points of the geometry are indicated with tiny circles. We not only see the center point, but also some at the compass points east, north, south and west of each circle. The latter ones were automatically created as part of the circle definition. Note that ¡DIANA draws the circles by default with four straight chords per quarter. This is only a matter of presentation, the exact circular shape will be applied for all manipulations concerning the circles.

Creating a plot file. As discussed earlier, screen-dumps are not very suitable for presentation in documents. Therefore we will now demonstrate how to create a picture in plot format. This is not only appropriate for this manual, but also for other technical documents about finite element analyses with DIANA.

plate.fgc

```
UTILITY SETUP PLOTTER FORMAT POSTSCRPT COLOUR
VIEW GEOMETRY ALL VIOLET
LABEL GEOMETRY LINES ALL VIOLET
LABEL GEOMETRY POINTS
DRAWING SAVE PLOTFILE geom1.ps
yes
initial geometry
```

The UTILITY SETUP PLOTTER FORMAT command, with the POSTSCRPT COLOUR option, causes ¡DIANA to write a plot file in POSTSCRIPT format [1], including colors, whenever you give the DRAWING SAVE PLOTFILE command. In this case we first give some VIEW and LABEL commands with the GEOMETRY option to draw the geometry and line labels in violet because the default yellow is barely visible on a white background, like paper.

Before actually writing the plot file, ¡DIANA asks for confirmation and for a short title which will be added below the frame. The plot file `geom1.ps` may be sent directly to a POSTSCRIPT device, or included in a document for instance in this manual [Fig. 2.8b].

> *In the sequel of this volume, as well as in all other volumes of the* DIANA *User's Manual, we will present* ¡DIANA *pictures in plot format rather than as screen dumps, without showing the applied* ¡DIANA *commands that were given to get the plot files.*

We have now defined the initial geometry of the model. What remains is to cut off the quarter part, define surfaces, and create the proper outer bound with straight lines. This will demonstrate only a few of the many ¡DIANA options which relieve us of the obligation to perform geometrical calculations of coordinates.

Quarter part with surfaces. We actually will define the model to be meshed via surfaces in the north-easterly quarter of the complete circular model. As the complete circle is divided in four equally sized lines you may create a point on two-third along line L5, i.e., the north-easterly section of the circumscribed circle [Fig. 2.8b]. To get a consistent mesh we also create the corresponding point on the inner circle.

`plate.fgc`

```
GEOMETRY SPLIT L5 0.66666667
GEOMETRY SPLIT L1 0.66666667
GEOMETRY LINE P2 P6
GEOMETRY LINE BETWEEN SHORTEST L11 P9
GEOMETRY SURFACE P1 P5 P9 P10
GEOMETRY SURFACE P10 P9 P11 P2
```

With the GEOMETRY SPLIT command we split lines L5 and L1 at two-third of their lengths. This creates two new points: P9 the vertex point on the outer edge and P10 on the inner edge respectively. Then the GEOMETRY LINE command defines a line between points P2 and P6, which forms the left edge along the vertical symmetry axis. This line is straight by default, and automatically named L11.

Next you must define the horizontal top line from the vertex P9 to the vertical symmetry line. The easiest way to do this is via the BETWEEN SHORTEST option which creates a line along the shortest distance between two geometrical parts. ¡DIANA will automatically create point P10 along the vertical edge.

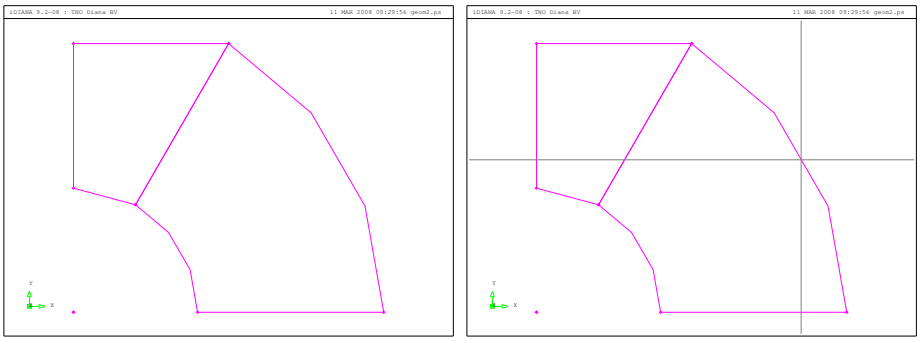
Now we have got all points that are necessary to define two surfaces via the SURFACE option. The surface definition requires the points to be specified in a circular sequence. ¡DIANA will automatically name the surfaces S1 and S2.

Displaying the geometry. To display the geometry we give the following commands.

plate.fgc

```
VIEW GEOMETRY S1 VIOLET
VIEW GEOMETRY +S2 VIOLET
CONSTRUCT SPACE WORK-BOX 10 8.7 0
EYE FRAME WORK-BOX
DRAWING CONTENTS MONITOR OFF
```

First the two surfaces are displayed in violet where the prefix plus sign for surface S2 causes its display to be superposed to that of surface S1. Next we give the CONSTRUCT SPACE WORK-BOX command to define a viewport that just fits the model of the quarter plate. The values 10, 8.7 and 0 specify the upper limits of the XYZ coordinates. With the EYE FRAME WORK-BOX command we effectuate the model display in the newly defined viewport. Unfortunately the monitor overlaps the upper-left point of the model display. Therefore we switch it off via the DRAWING CONTENTS MONITOR command. This clearly displays the two surfaces [Fig. 2.9a].



(a) geometry display (b) pointing with the graphics cursor

Figure 2.9: Model geometry before correction

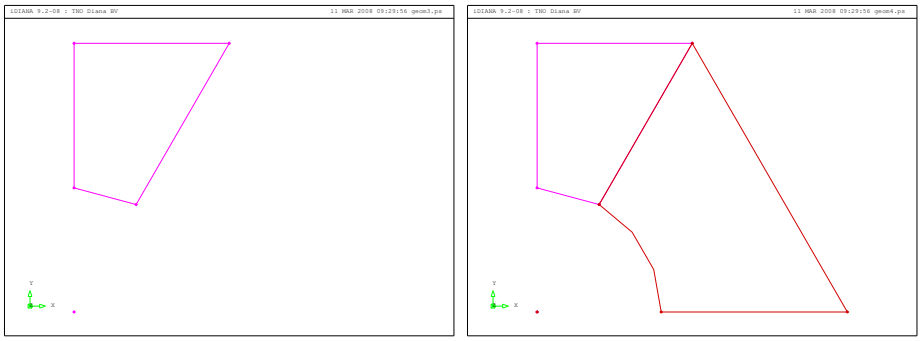
Correcting the geometry. The geometry display shows that the one outer edge is curved. This is due to the original definition as part of the circumscribed circle. In the actual model this edge must be a straight line, so the current model needs some correction.

plate.fgc

```
UTILITY DELETE L5
yes
VIEW GEOMETRY CURRENT VIOLET
GEOMETRY SURFACE P1 P5 P9 P10
VIEW GEOMETRY +S3 RED
```

First we delete the curved line via the DELETE option. You could directly type the line name L5 behind the command, as shown. However, particularly if the line name is unknown, it is more convenient to indicate the line to be deleted interactively via the graphics cursor [Fig. 2.9b]. In reality, this cursor shows up as white crosshairs when you move the mouse cursor into the black viewport or when you press the ENTER key immediately after having typed the DELETE option. You may move the crosshairs with the mouse to the vicinity of the center of the geometric part to be picked, i.e., the curved line. When you now click the left mouse button ¡DIANA will fill in the line name L5 behind the DELETE option on the command line.

You are asked for confirmation of the deletion. If the answer is 'yes' then also the surface S1 which contained the deleted line will be deleted. This is proved via the VIEW GEOMETRY CURRENT command [Fig. 2.10a]. If you now redefine



(a) one remaining surface (b) added surface

Figure 2.10: Correcting the plate model geometry

the surface with the same points as previously then ¡DIANA will automatically create a new line to complete this surface. By default the new line will be a straight one, which is just what we want! The VIEW GEOMETRY command adds the new surface S3 to the display of the geometry [Fig. 2.10b].

2.3.4 Creating a Set

As there are more geometric parts than actually are needed for the model, e.g., the complete inner and circumscribed circle, it is convenient for future reference to the real model to collect the two surfaces that form the quarter plate in a named set.

plate.fgc

```
CONSTRUCT SET OPEN PLATE
CONSTRUCT SET APPEND S2
CONSTRUCT SET APPEND S3
```

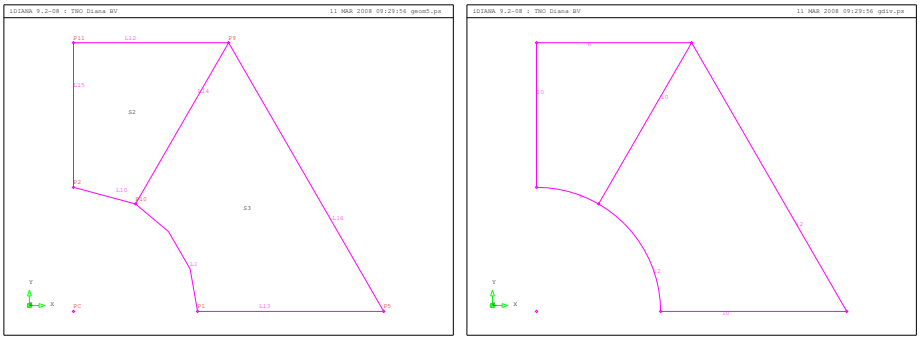
```
CONSTRUCT SET CLOSE
```

Maintenance of sets is done via the CONSTRUCT SET command. With the OPEN option we open a new set named PLATE and with the APPEND option we put the two surfaces in the set. Then the CLOSE option closes the set. We may now use the set name PLATE to refer to the model of the quarter plate.

plate.fgc

```
VIEW GEOMETRY PLATE VIOLET
LABEL GEOMETRY POINTS
LABEL GEOMETRY LINES CURRENT VIOLET
LABEL GEOMETRY SURFACES CURRENT WHITE
```

The VIEW GEOMETRY command with the set name now directly displays the model of the two surfaces [Fig. 2.11a]. The LABEL commands label the currently



(a) points, lines, surfaces (b) divisions

Figure 2.11: Geometry with labels

displayed geometric parts. Note that the WHITE option displays labels in white on the screen, against the black background of the viewport. For the plot file ¡DIANA transfers the 'color' white to black.

2.3.5 Meshing Procedure

Now that the geometry has been defined completely we may continue with the meshing process: specifying the DIANA element type for plate elements and the fineness of the mesh, and then performing the actual generation of the mesh.

plate.fgc

```
MESHING TYPES ALL QU8 CQ24P
MESHING DIVISION PROPAGATE L13 10
MESHING DIVISION PROPAGATE L1 12
MESHING DIVISION PROPAGATE L10 6
LABEL GEOMETRY OFF
```

```
LABEL GEOMETRY DIVISIONS
MESHING GENERATE
```

Due to the MESHING TYPES command, all surfaces will be meshed with the generic QU8 elements, where 'generic' means that the element type only describes the shape of the element, i.e., an eight-node quadrilateral, and not the application or stress situation. If we use the command menu and point at this element type, the menu shows all the DIANA elements that match the generic QU8 element type for the previously specified model type. In this case we choose the CQ24P plate bending element.

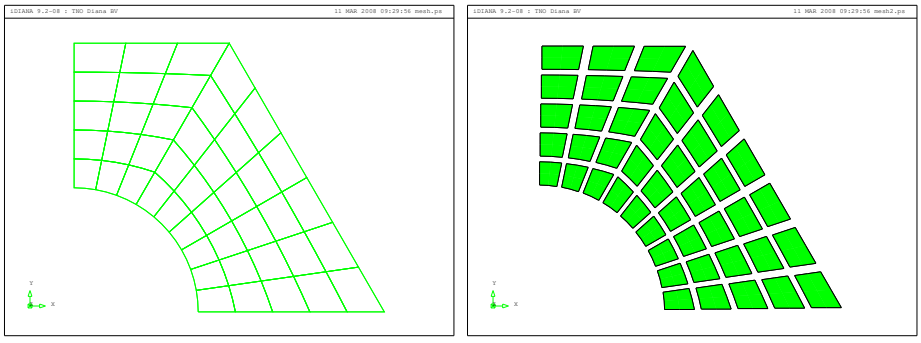
The DIVISION option controls the number of elements that ¡DIANA will create, i.e., the fineness of the mesh. In this case we first specify an explicit division for a few lines. The PROPAGATE option causes the same division to be applied for the lines' opposite neighbors. Note that you must specify twice as much divisions as you want to have elements along a line because the elements have midside nodes.

After having checked the divisions via the LABEL GEOMETRY DIVISIONS command [Fig. 2.11b], we may give the MESHING GENERATE command to let ¡DIANA generate the mesh.

plate.fgc

```
VIEW MESH
VIEW OPTIONS SHRINK
VIEW HIDDEN SHADE
```

After generation, the mesh will not be displayed automatically. Therefore we give the VIEW MESH command which, by default, displays the mesh in green wire netting style [Fig. 2.12a]. This style does not clearly show unwanted holes.



(a) default display style (b) shrunken elements & color fill

Figure 2.12: Generated mesh

To check for that, two viewing options are appropriate: 'shrunken elements' and 'color fill'. In this case we apply these simultaneously, respectively via the SHRINK and HIDDEN SHADE viewing options [Fig. 2.12b].

2.3.6 Boundary Constraints

Now that the mesh has been generated we have to define the boundary constraints. For this example these consist of the rigid supports and the symmetry conditions. We define boundary conditions via the PROPERTY BOUNDARY CONSTRAINT command.

plate.fgc

```
PROPERTY BOUNDARY CONSTRAINT P5 Z
PROPERTY BOUNDARY CONSTRAINT P9 Z
PROPERTY BOUNDARY CONSTRAINT L13 RX
PROPERTY BOUNDARY CONSTRAINT L15 RY
```

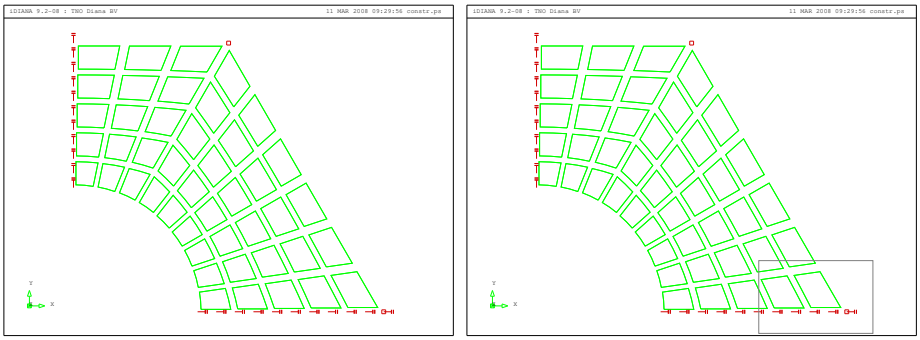
The commands with the Z option specify a rigid support for the translation in the global Z direction, i.e., vertically, at the two vertex points of the quarter hexagonal plate. The commands with the RX and RY option respectively specify a suppressed rotation around the global X and Y directions. These model the symmetry condition along the horizontal and vertical edge. Note that it is not necessary to specify symmetry conditions for in-plane displacements because these are not part of the degrees of freedom for plate bending elements.

We will now check the boundary constraints by labeling the mesh. As mesh labels cannot be displayed on a color filled mesh we first switch that off.

plate.fgc

```
VIEW HIDDEN OFF
LABEL MESH CONSTRNT
EYE ZOOM .647 .295 .948 .115
```

The LABEL MESH CONSTRNT command displays the constraints with square-headed nails pointing in the direction of the suppressed displacement [Fig. 2.13a]. Note that in the two-dimensional view, the vertical supports appear as squares. Also note that suppressed rotations are displayed with dual-head nails.



(a) entire model (b) zoom window

Figure 2.13: Boundary constraints

Zooming. For a closer look at the displayed boundary conditions you may zoom in at a supported edge of the model. Therefore we give the EYE ZOOM command which by default requires the normalized coordinates of the zoom window within the current viewport. Instead of typing these on the command line you may move the mouse cursor into the viewport and drag a zoom window, from upper-left to lower-right, while pressing the left mouse button [Fig. 2.13b]. When you now release the mouse button, ¡DIANA will substitute the coordinates of the zoom window on the command line and display the contents of the zoom window in the entire viewport [Fig. 2.14]. Note that due to the shrunken

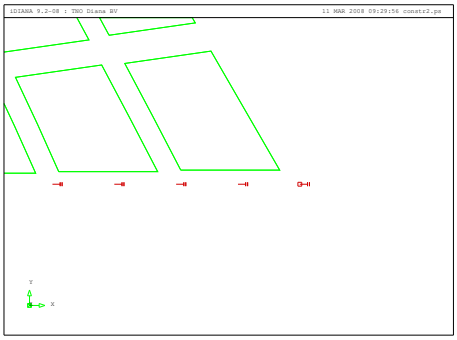


Figure 2.14: Boundary constraints – zoomed-in

elements view the supports seem to be 'in the air'. In reality they are attached to the nodes of the finite element mesh.

Instead of the ZOOM option we could have used the standard OpenGL features to zoom and translate the model interactively: press and hold down the CTRL key and simultaneously drag the mouse cursor while respectively pressing the middle or the right button.

2.3.7 Loading Definition

We will now apply the loads to the model via some PROPERTY LOADS commands. There are two load cases: case 1 is the dead weight load to the entire model, case 2 is a distributed line load along the inner circle of the plate.

plate.fgc

```
PROPERTY LOADS GRAVITY 1 ALL -9.8 Z
PROPERTY LOADS PRESSURE 2 L1 -20000. Z
PROPERTY LOADS PRESSURE 2 L10 -20000. Z
```

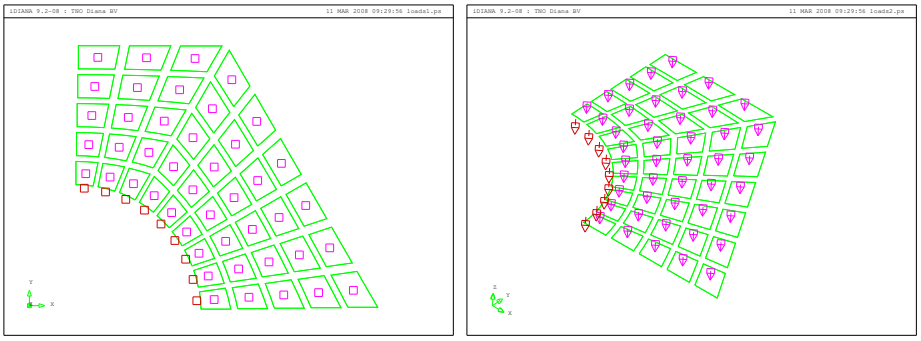
The dead weight load is specified with the GRAVITY load class and an acceleration of gravity $g = 9.8$ in the $-Z$ direction. The distributed line load is specified

with two commands, one for each line of the inner circle.[5] The load class for a distributed load is PRESSURE, the value and the Z option specify the size and the direction. We will now check the loading by labeling the mesh. Therefore we first revert to a view of the entire mesh and switch off the labels of the boundary conditions.

plate.fgc

```
EYE FRAME
LABEL MESH OFF
LABEL MESH LOADS 1
LABEL MESH LOADS 2 RED
EYE ROTATE TO 45 30 30
```

The LABEL MESH LOADS commands display the loads on the elements. For clarity we apply different colors for the two load cases: the default violet for case 1 and red for case 2 [Fig. 2.15a]. Because we look in the direction of the load we see



(a) view from above (b) bird's-eye view

Figure 2.15: Loading

little squares which actually represent the heads of the displayed arrows. To see the real arrows of the loading we change to a bird's-eye view of the model [Fig. 2.15b]. Here we use the ROTATE option to specify a viewing direction with angles relative to the XYZ model axes. Instead of this option we could have used the standard OpenGL feature to rotate the model interactively: press and hold down the CTRL key and simultaneously drag the mouse cursor while pressing the left button.

2.3.8 Material and Physical Properties

To complete the model we will now define its material and physical properties. Therefore ¡DIANA offers an interactive user interface with so-called property

[5] Instead of specifying a name on the command line you may pick the line via the graphics cursor, as explained for the DELETE option [§ 2.3.3 p. 22].

forms. To get such a form you must open the View menu (1) and choose Property Manager (2) [Fig. 2.16]. The Property Manager dialog shows up [Fig. 2.17].

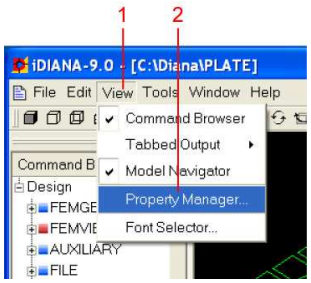


Figure 2.16: Opening the Property Manager dialog

Material properties. Now we choose the Materials tab (3) for specification of material properties and click the Create New button (4). In the Material Name

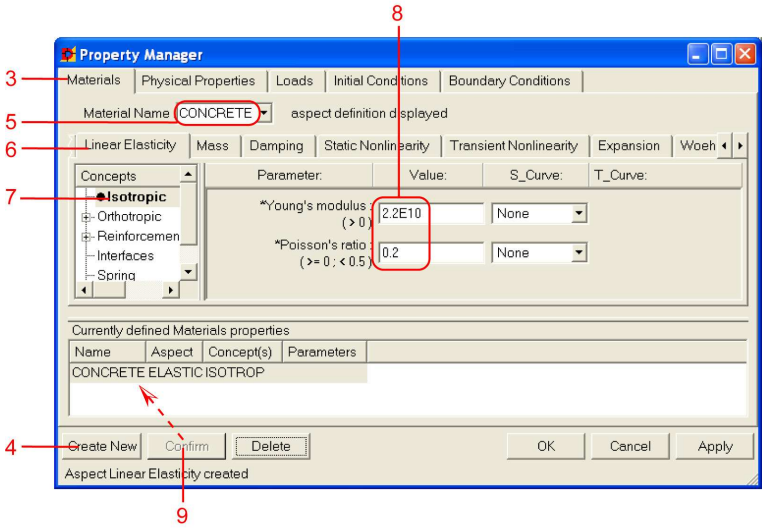


Figure 2.17: Specification of material properties for linear elasticity

field on top we type the name of a new material: CONCRETE (5). Depending on the type of the model there are tabs for the various aspects of the material properties. First we choose Linear Elasticity (6). Each aspect may have various concepts which show up in the Concepts tree where we choose Isotropic (7). We may now fill in the parameters for isotropic linear elasticity: *Young's modulus and Poisson's ratio (8). The leading star in *Young's modulus indicates that this parameter is obligatory, there is no default value. When we click the Confirm

button (9) the new material concept is saved and listed in the Currently Defined field.

The second material aspect for this model is Mass, which we choose by clicking the tab (10) [Fig. 2.18]. The concept here is Mass Density (11), for

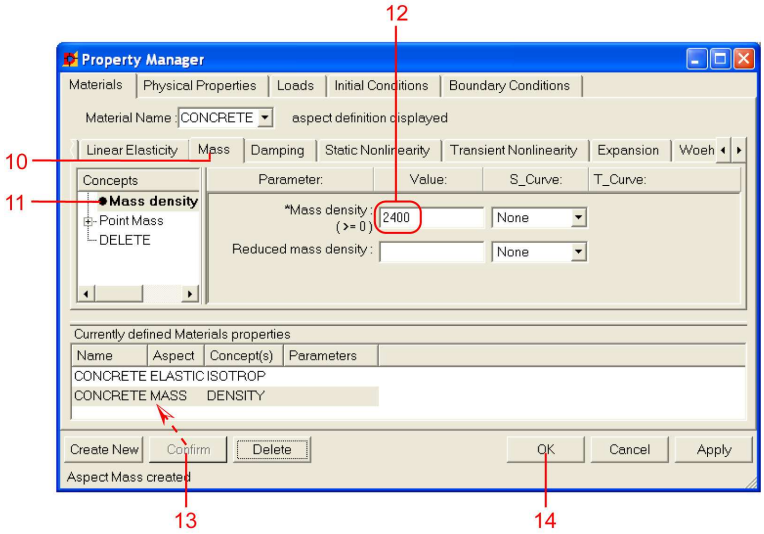


Figure 2.18: Specification of material properties for mass

which we fill in the appropriate value (12) and click Confirm (13). We have now specified all material parameters for the analysis of this model and click OK to save the material CONCRETE (14).

Physical properties. The procedure to specify the physical properties, in this case the thickness of the plate, is analogous to that for the material properties. First we click the Physical Properties tab (15) [Fig. 2.19]. Then we click Create New (16) and fill in the name THICK for the properties that we will specify (17). Then we activate the Geometry aspect tab (18) and choose Plate Bending → Isotropic (19). We fill in the thickness of the plate (20) and accept the proposed value of 1.5 for the shape factor [Vol. *Element Library*]. Finally we Confirm (21) and click OK to save the specified properties (22).

Property assignment `plate.fgc`

```
PROPERTY ATTACH PLATE CONCRETE THICK
```

With the PROPERTY ATTACH command we assign the properties CONCRETE and THICK, that we have just specified via the property forms, to all the elements in set PLATE which forms the model of the quarter hexagonal plate.

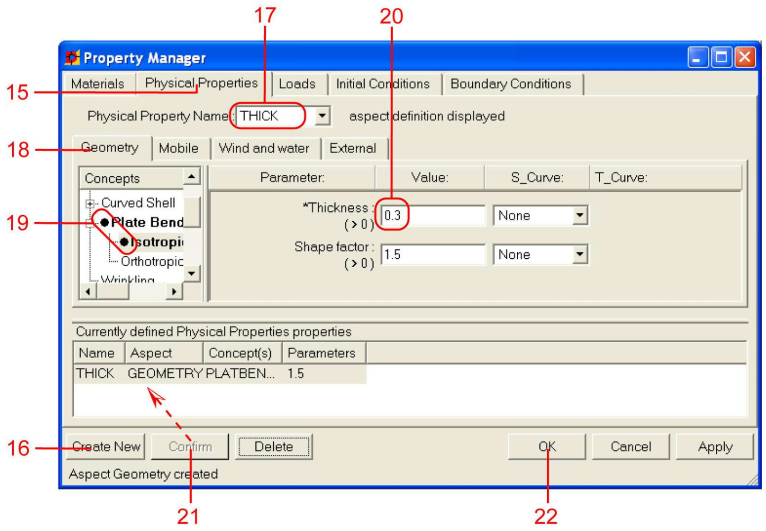


Figure 2.19: Specification of physical properties for geometry

2.3.9 Running a Command File

The DIANA User's Manual comprises a lot of examples of model preparation, analysis, and postprocessing. This particular example is called plate6 and you may find the related files in the DIANA installation directory at

`Examples/GetStart/plate6`

You may copy the file `plate.fgc` to your own directory (folder), possibly modify it, and then let ¡DIANA read it via the UTILITY READ BATCH command.

```
FEMGEN PLATE
UTILITY READ BATCH plate.fgc
```

If the command file is syntactically correct you will see the model being created live on the screen.

2.3.10 Saving the Current Model

The model is now complete and we can save it on an ¡DIANA database. We start the saving procedure [Fig. 2.20] by double clicking the SAVE command in the Command Browser (1). In the pop-up Confirmation dialog we click Yes (2) which brings a dialog where we may type a short description of the model (3). Then we click OK to save the model (4). ¡DIANA confirms a successful save in the Messages tab. Note that the name of the model database is PLATE.G71.

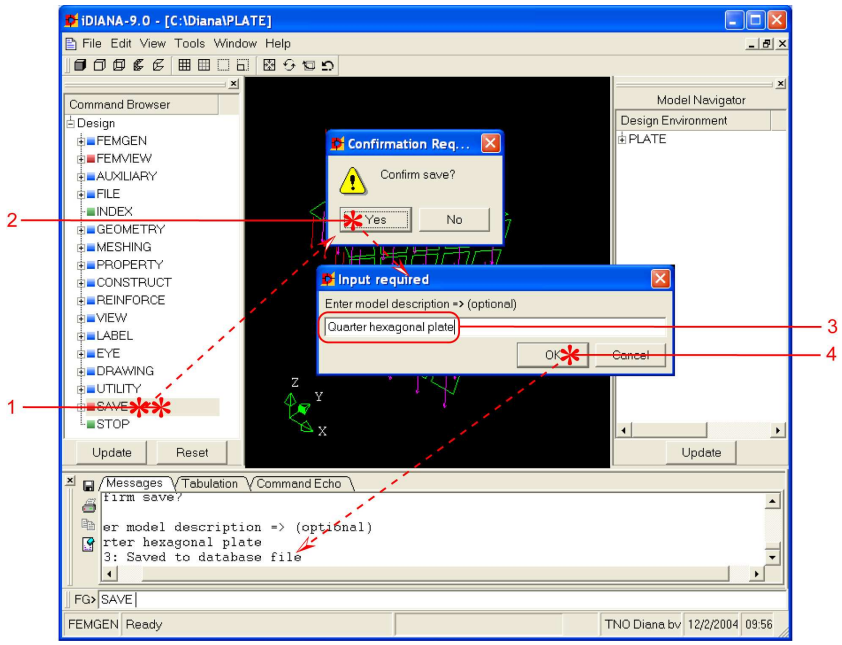


Figure 2.20: Saving the model

The letter `G` in the extension indicates that this is a database for the Design environment, `71` indicates the version. We may reopen the model in the Design environment should we ever want to modify it.

Commands

```
SAVE
yes
Quarter hexagonal plate
```

If we add the above commands to the end of the command file `plate.fgc`, the ¡DIANA run would automatically save the model.

2.4 Performing the Analysis

The analysis procedure of the model comprises three stages: the initiation, the specification of analysis options and the actual calculation by DIANA.

2.4.1 Initiation

To initiate the analysis we can choose between an interactive procedure and commands.

Interactive [Fig. 2.21]. We open the File menu (1) and choose Run → An Analysis (2). The Run an Analysis dialog pops up where we choose the appropriate

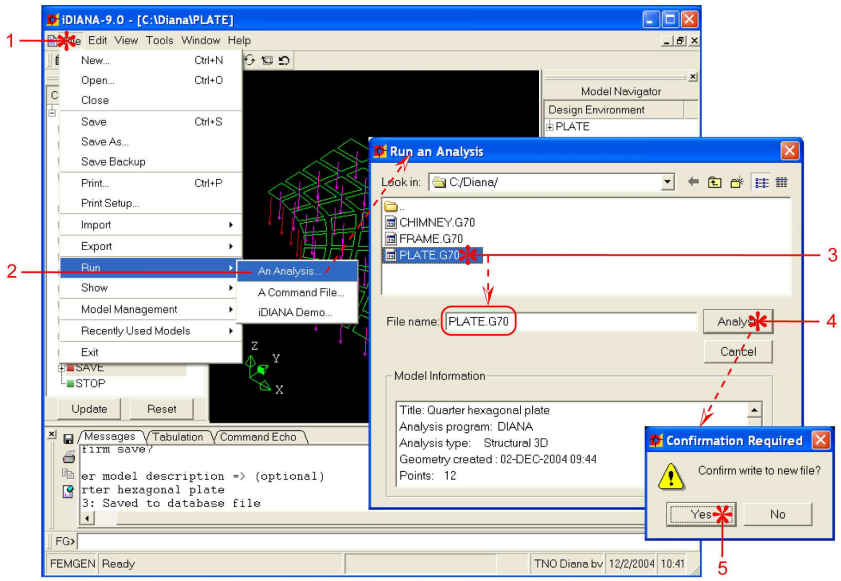


Figure 2.21: Initiating the analysis

model database by clicking its name PLATE.G71 in the list box (3). The name appears in the File Name box and some model information is shown in the pane below. We now click the Analyse button to start the analysis (4). An analysis requires an input data file in DIANA batch format [Ch. 3]. ¡DIANA will automatically write this file after our confirmation (5).

Commands

```
UTILITY WRITE DIANA
yes
FILE CLOSE
yes
ANALYSE PLATE
```

The UTILITY WRITE DIANA command will write the model in DIANA batch input format. We must confirm the writing of a new file. We close the model and enter the Index environment via the FILE CLOSE command and type the ANALYSE command with the name of the model PLATE.

Analysis setup. The Analysis Setup dialog appears [Fig. 2.22-left]. The three boxes show default names which we accept for this example. The Working Directory box indicates the place where DIANA will create output files, log files etc. The Filos File box shows the current name of the FILOS file, i.e., the central

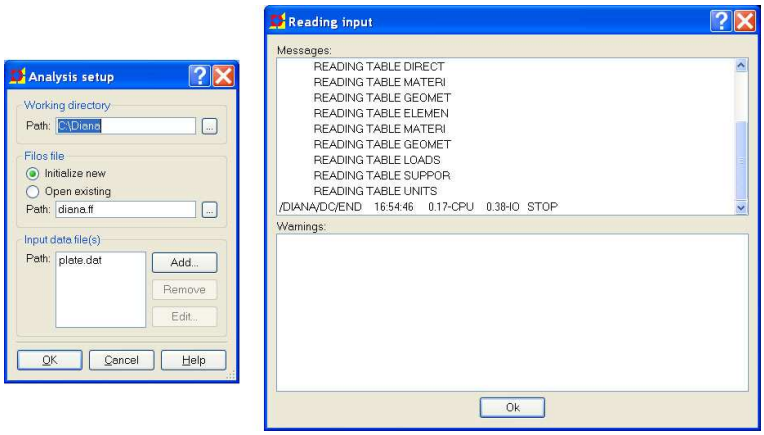


Figure 2.22: Analysis setup and input reading

database for the analysis of the model. Here we accept Initialize New to indicate that this is a new analysis. The Input Data File(s) box shows the name of the input data file that was recently written. With a click on OK, DIANA starts to read the input data file.

Reading the input data. The Reading Input dialog pops up and shows a log of the reading process [Fig. 2.22-right]. In the Messages box we see all the input tables being read, and finally a termination log line. Any messages, errors or warnings, would appear in the Warnings box. In this case we get no warnings and may click OK.

Selecting the analysis type. After termination of the reading process the Select Analysis Type dialog appears [Fig. 2.23-left] in which we must indicate the analysis type. We accept the default Structural linear static analysis and click OK.

2.4.2 Analysis Options

Next, the DIANA Analysis dialog pops up giving the different modules that are called during the analysis, as well as the modules that were called previously [Fig. 2.23-right] . By right-clicking on the Structural linear static entry and choosing Edit... we enter the Structural Linear Static Settings dialog where we may set various analysis options. [Fig. 2.24-left]. The different tabs correspond to specific tasks in the analysis process: Model for the evaluation and setup of the finite element model, Solve for the solution procedure, and Output for the output selection of analysis results. For most options DIANA has preset appro-

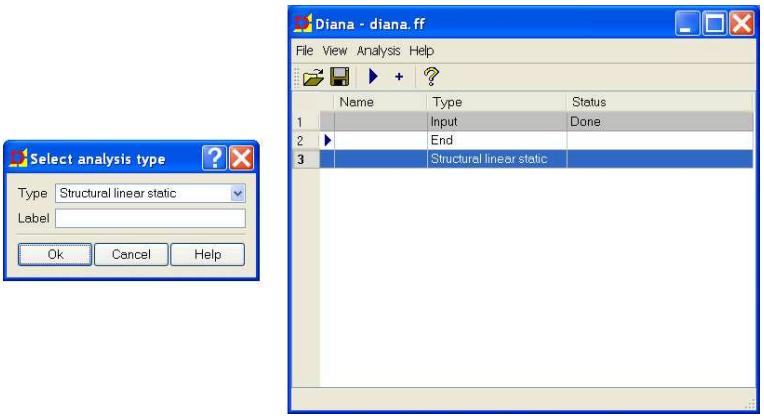


Figure 2.23: Analysis type selection and DIANA Analysis dialog

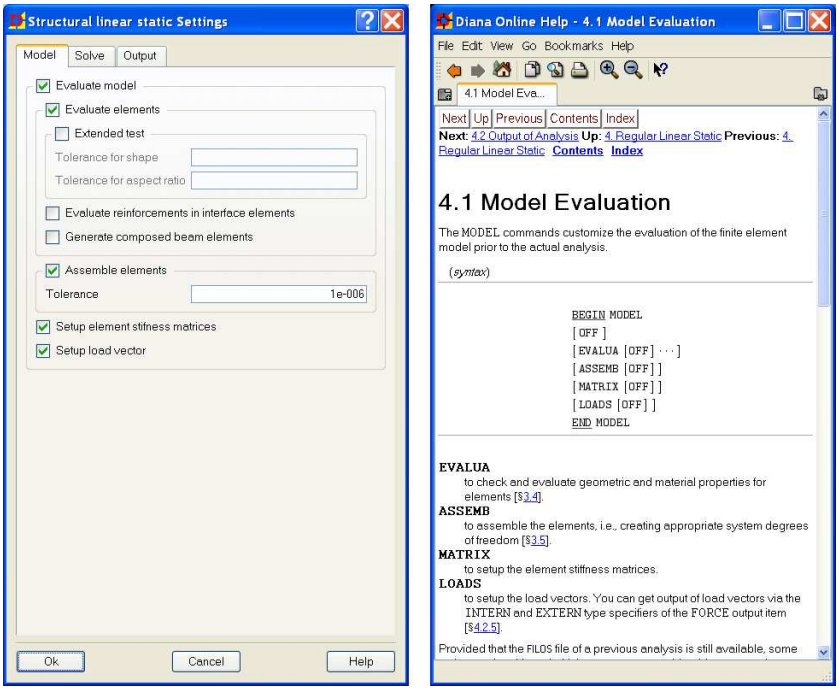

Structural linear static Settings
Model Solve Output
Evaluate model
Evaluate elements
Extended test
Tolerance for shape
Tolerance for aspect ratio
Evaluate reinforcements in interface elements
Generate composed beam elements
Assemble elements
Tolerance 1e-006
Setup element stifness matrices
Setup load vector
Ok Cancel Help
Diana Online Help - 4.1 Model Evaluation
File Edit View Go Bookmarks Help
Next Up Previous Contents Index
Next: 4.2 Output of Analysis Up: 4. Regular Linear Static Previous: 4. Regular Linear Static Contents Index
4.1 Model Evaluation
The MODEL commands customize the evaluation of the finite element model prior to the actual analysis.
(syntax)
BEGIN MODEL
[OFF]
[EVALUA [OFF] ···]
[ASSEMB [OFF]]
[MATRIX [OFF]]
[LOADS [OFF]]
END MODEL
EVALUA
to check and evaluate geometric and material properties for elements [§3.4].
ASSEMB
to assemble the elements, i.e., creating appropriate system degrees of freedom [§3.5].
MATRIX
to setup the element stiffness matrices.
LOADS
to setup the load vectors. You can get output of load vectors via the INTERN and EXTERN type specifiers of the FORCE output item [§4.2.5].
Provided that the FILOS file of a previous analysis is still available, some

Figure 2.24: Analysis options and on-line help

priate defaults.[6] Pressing the F1 key brings a browser window with the section of the DIANA User's manual regarding the subject in the analysis window that

[6] See Volume *Analysis Procedures* for a comprehensive description of analysis options.

currently has the keyboard control [Fig. 2.24-right]. In this case we accept the defaults for all analysis options, except for the selection of output results.

Output selection. By default DIANA will output the Cauchy stresses and the distributed bending moments and forces. However, for a plate bending model like the one in this example, the Cauchy stresses are less appropriate. Moreover, we would also like to see the displacements and reaction forces. We may achieve this via a user-specified selection [Fig. 2.25]. Therefore we first click the Output

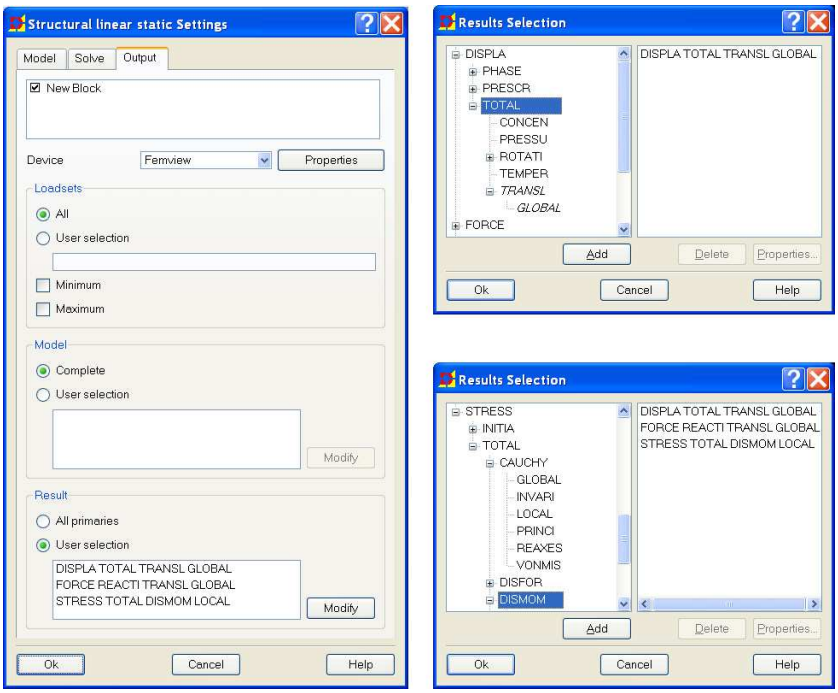


Figure 2.25: Output selection

tab, then New Block for a new selection and User Selection in the Result box. If we now click Modify the Results Selection dialog will appear where we may customize the selection of analysis results to be output.

First we click DISPLA to unfold the selection options for displacements. We see the default settings highlighted: TOTAL TRANSL GLOBAL which stands for the total translations in the global XYZ directions. We agree with that and click Add to move the selected result into the list of selections. We do the same for FORCE which adds the reaction forces to the selection list (not shown).

For the stresses we check the selection of the bending moments. Therefore we click STRESS to unfold the options for stress selection. At first we see the default CAUCHY highlighted which stands for the Cauchy stresses. Here we don't agree and click DISMOM and LOCAL to select the distributed moments in the local xy

directions. Again by clicking Add we add the current selection to the selection list.

We have now selected all analysis results that we want to be output and click Close to make the selection active for the analysis. The Results Selection dialog disappears and we are back in the DIANA Structural Linear Static Settings dialog where the selected analysis results are displayed in the Result box. We will make no further changes to the settings of analysis options and click OK.

2.4.3 Calculation

In the menu of the DIANA Analysis dialog we choose Analysis → Run (1), or we click the ▶ tool button. This starts the analysis. While running, DIANA logs the analysis process in the Calculating dialog [Fig. 2.26]. There are two

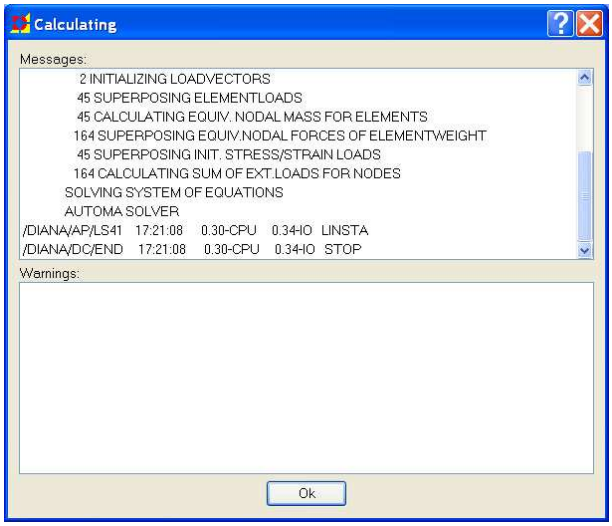


Figure 2.26: Analysis execution

boxes: the Messages box with log lines, and the Warnings box with warnings and error messages. When the last log line with STOP appears, the calculation has been terminated. If there are no error messages we may click OK (2) and the Calculating dialog will disappear.

2.5 Postprocessing

The analysis run has created an ¡DIANA database called PLATE.V71. The letter V in the extension indicates that this is a database for the Results environment where we can assess the analysis results. The number 71 indicates the version. We may open this database, and enter the Results environment, in two ways: interactively via the File menu or with a command.

Interactive [Fig. 2.27]. Choosing File → Open in the Menu Bar of the ¡DIANA working window (1) brings the Open dialog where we can choose the appropriate database PLATE.V71 (2) and click Open (3).

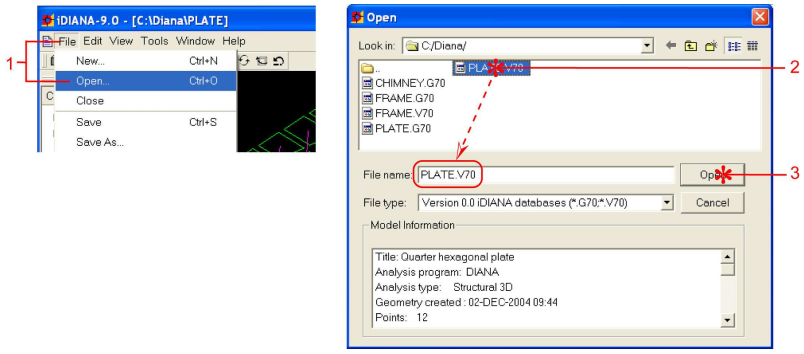


Figure 2.27: Entering the Results environment

Command

```
FEMVIEW PLATE
```

The FEMVIEW command with the model name PLATE as parameter opens the database of this model for the Results environment.

Either way of entering the Results environment brings the ¡DIANA working window as shown in Figure 2.28. The **FV>** prompt indicates that we are in the Results environment (1). Initially the Monitor shows the name of the model (2) and in the Graphics Window ¡DIANA displays an outline view (3). The Command Browser now displays the top-level commands for the Results environment (4). We start with the following general commands.

plate.fvc

```
UTILITY TABULATE LOADCASES
VIEW MESH
```

The UTILITY TABULATE LOADCASES command tabulates all load cases and their available results in the Tabulation tab:

lcase.tb

```
;
; Model: PLATE
;
;     LOADCASE DATA
;
;  Name          Details and results stored
;  ----          --------------------------
;
;  MODEL         STATIC  "Model Properties"
;                Element   :  THICKNES*
```

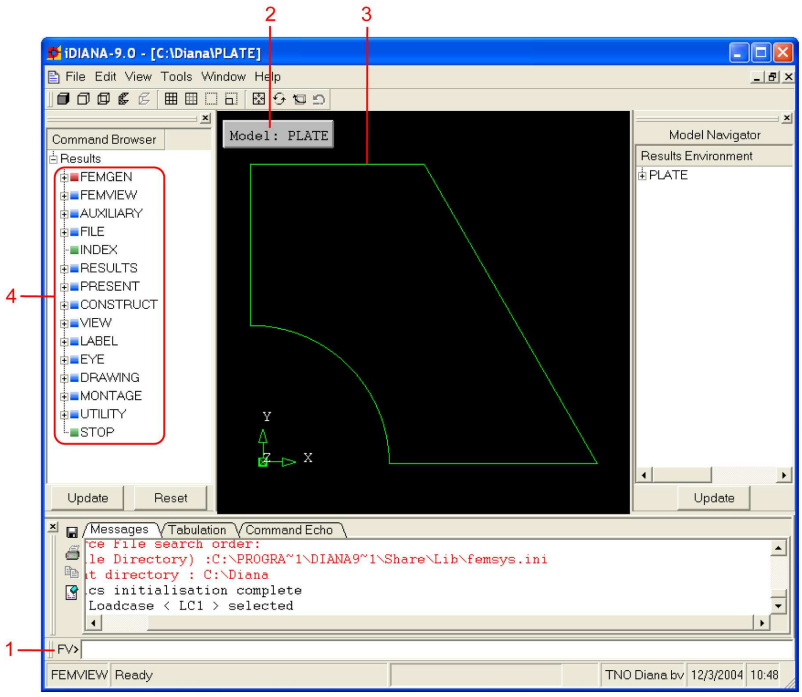


Figure 2.28: The Results working window

```
;
;  LC1          STATIC  "Load case 1"
;               Nodal     :  DTX....G  FBX....G
;               Element   :  EL.MXX.L
;
;  LC2          STATIC  "Load case 2"
;               Nodal     :  DTX....G  FBX....G
;               Element   :  EL.MXX.L
;  * Indicates loads data
;
```

There are two load cases: LC1 the dead weight and LC2 the line load along the inner circular edge. The available analysis results are the total displacements DT and support reactions FB in the nodes, and bending moments EL.M for the elements. To prepare the results presentation we first display the undeformed mesh in the default green wire netting style by giving the VIEW MESH command.

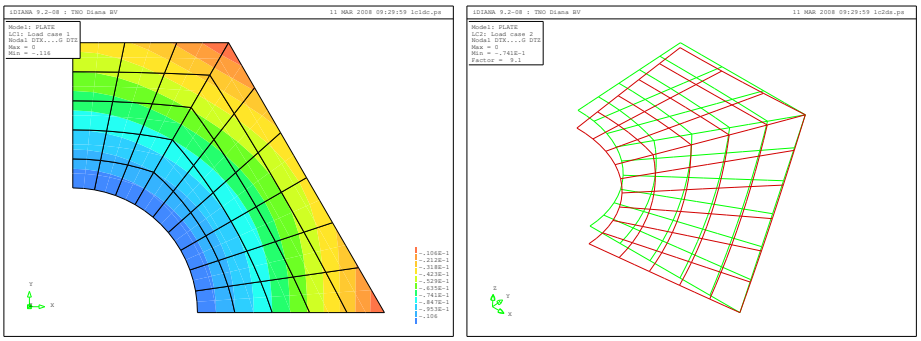
2.5.1 Displacements

¡DIANA can present the displacements of a finite element model in various styles. We will demonstrate the most appropriate ones for this example: contour plot and deformed mesh.

Contour plot `plate.fvc`

```
RESULTS LOADCASE LC1
RESULTS NODAL DTX....G DTZ
PRESENT CONTOUR LEVELS
```

First we select the analysis results to be displayed with two RESULTS commands: the LOADCASE option selects load case LC1. The NODAL option with the DT attribute selects the displacements in the nodes. Furthermore, with DTZ, we select the vertical (Z) component of the displacements. To present the selected results we give the PRESENT command. The CONTOUR LEVELS options asks ¡DIANA to display the contours for the selected result in default style: color filled with ten levels [Fig. 2.29a].



(a) load case 1 u_Z contours (b) load case 2 deformation

Figure 2.29: Displacements

Results monitor. The monitor in the upper-left corner of the viewport gives some information about the displayed results, notably the extreme value which is -0.116 in this case and indicates the maximum vertical displacement. ¡DIANA also displays a legend in the lower-right corner of the viewport which gives the bounding values for each color. The colors are modulated from red for the maximum to blue for the minimum. But take care! As the displacements are all negative, i.e., downward in the $-Z$ direction, the blue areas indicate the largest displacements.

Deformed mesh `plate.fvc`

```
RESULTS LOADCASE LC2
EYE ROTATE TO 45 30 30
EYE FRAME
PRESENT SHAPE
```

To demonstrate the display of a deformed mesh we first select the results for load case LC2. With no further RESULTS command the vertical displacements will remain selected. A deformation in the viewing direction would be invisible.

Therefore we change to the familiar bird's-eye view via the EYE commands. Next the PRESENT SHAPE command displays the deformed mesh in red [Fig. 2.29b]. The results monitor now also shows the multiplication factor that ¡DIANA has applied to achieve an easily perceptible deformation, in this case 9.1×.

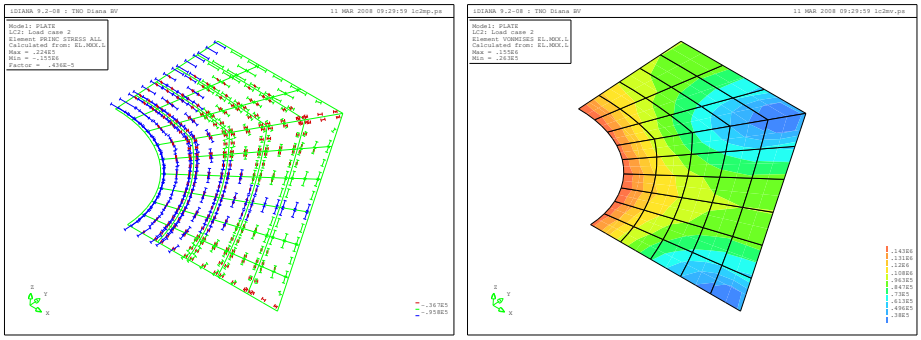
2.5.2 Bending Moments

We will now make some plots for the bending moments of the currently selected load case LC2.

Vector plot `plate.fvc`

```
RESULTS ELEMENT EL.MXX.L MXX
RESULTS CALCULATE P-STRESS ALL
PRESENT VECTORS
```

First we select the bending moments in the elements via the ELEMENT option and the EL.M... attribute. Because we will let ¡DIANA calculate the principal moments $m_{1,2}$ the component is arbitrary, here we choose MXX for m_{xx}. Then we ask ¡DIANA to calculate the principal moments via the RESULT CALCULATE P-STRESS command. The PRESENT VECTORS command displays the principal moments $m_{1,2}$ in vector style [Fig. 2.30a].



(a) vectors for principal moments (b) contours for equivalent moments

Figure 2.30: Bending moments

Contour plot `plate.fvc`

```
RESULTS CALCULATE VONMISES
PRESENT CONTOUR LEVELS
```

Contour plots are especially instructive for scalar or single value results. To display a contour plot of the bending moments we need the equivalent moments. Therefore we ask ¡DIANA to calculate these from the currently selected result item via the VONMISES option. Then the PRESENT CONTOUR LEVELS command displays the contours [Fig. 2.30b].

2.5.3 Support Reactions

Finally we will assess the support reactions, acting at the corners of the hexagonal outer edge by displaying their numerical values.

Numerical display `plate.fvc`

```
RESULTS NODAL FBX....G FBZ
PRESENT OPTIONS NUMERIC MODULATE OFF
PRESENT NUMERIC
```

The NODAL option with the FB attribute and the FBZ component selects the vertical reaction forces in the nodes. For value display color modulation is not very suitable. Therefore we switch that off via the NUMERIC MODULATE option then the PRESENT NUMERIC command displays the values of the reaction forces at their proper location [Fig. 2.31].

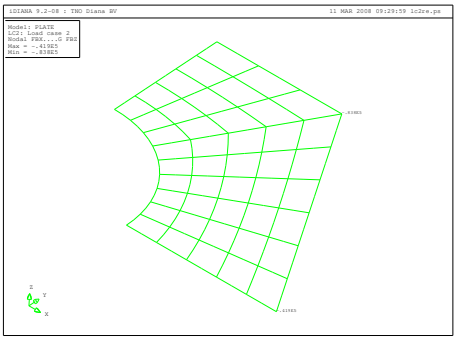


Figure 2.31: Support reactions

2.6 Leaving Interactive DIANA

We now terminate this example and may leave the ¡DIANA interactive session. Again, this can be done interactively or via a command.

Interactive [Fig. 2.32]. Choosing File → Exit in the Menu Bar (1) brings the Confirmation dialog where we click Yes (2).

Command

```
STOP
yes
```

The STOP command with confirmation also exits the ¡DIANA session.

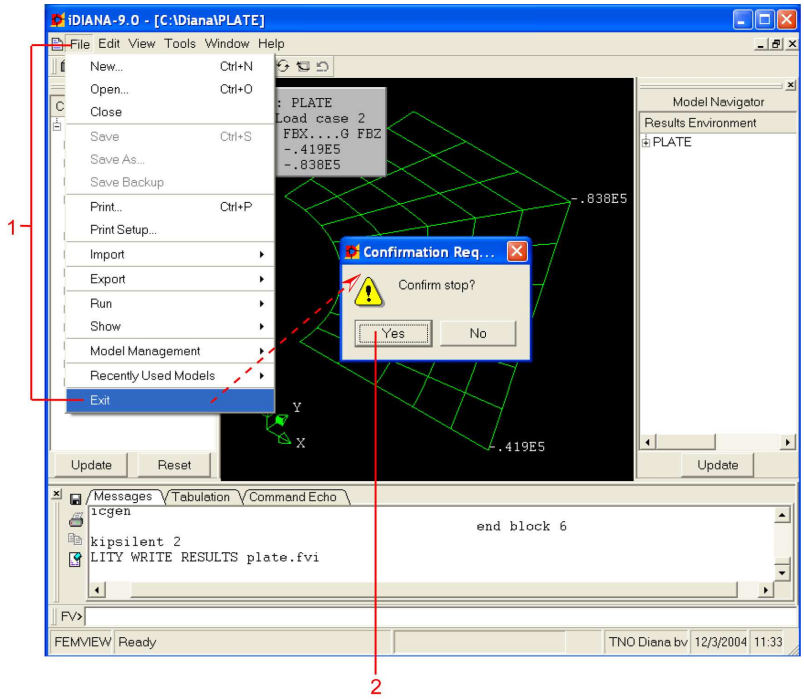


Figure 2.32: Leaving the DIANA Graphical User Interface

Chapter 3

Batch User Interface

Most users, even the more experienced ones, will use the ¡DIANA Graphical User Interface as introduced in Chapter 2. However, as a novice user you are encouraged to read this chapter as well because it not only introduces the DIANA batch interface, but also the setup of the DIANA User's Manual and the general aspects of performing a Finite Element Analysis with DIANA. Moreover, most volumes of the User's Manual formally describe the input, analysis, and output of a finite element model in terms of the batch interface, which is another good reason to study this chapter.

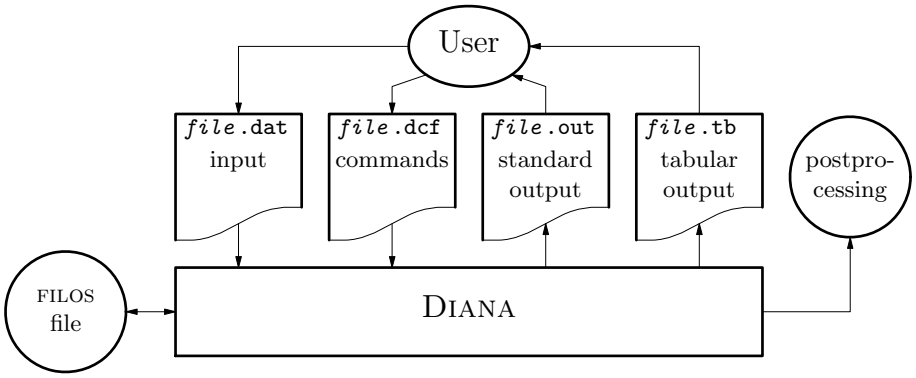


Figure 3.1: Batch interface

What is the batch interface? In the DIANA batch interface [Fig. 3.1], you must supply DIANA with two files: an *input* data file which describes the finite element model [§ 3.1], and a *command* file which tells DIANA how to analyze it [§ 3.2.1]. From these two files DIANA can setup and solve the system of equations and produce analysis results on a *tabular output* file [§ 3.2.3], or on a *postprocessing* file for interactive graphics postprocessing with ¡DIANA [§ 3.2.4].

The next sections describe the various parts of the batch interface in more detail. You will also meet two more files: the FILOS file which is the internal database where DIANA stores all intermediate data, and the *standard output* file which informs you about the performance of the analysis job [§ 3.2.2].

3.1 Input Data File

The input data file is a text-format file which you may produce and modify with any convenient text editor, for instance `vi` or `xedit` on a UNIX system, or NOTEPAD on a PC under MS-Windows. The input data file describes the entire finite element model, including the node coordinates, elements and connectivity, boundary conditions, loading etc. See § A.2 on page 85 for a formal description of the input data format in the batch interface.

Example. To make the descriptions of the batch interface more realistic we will use a simple example of a two-dimensional crossed frame as shown in Figure 3.2.[1] For a first impression, we show the complete input data file for this example below.

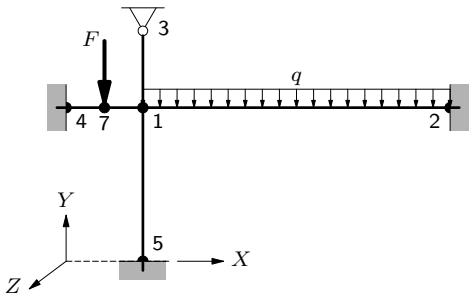


Figure 3.2: Two-dimensional crossed frame

Input data *file*`.dat`

```
2-D Crossed Frame
Example for Volume "Getting Started"
'COORDI' DI=2
 1    1.0  2.0
 2    5.0  2.0
 3    1.0  3.0
 4    0.0  2.0
 5    1.0  0.0
```

[1] The example is called `cframe` and you may find the related files in the DIANA installation directory at `Examples/GetStart/cframe`. For more examples see also Volume *Analysis Examples*.

```
 7    0.5  2.0
'ELEMEN'
CONNEC
 1    L6BEN  4  7
 2    L6BEN  7  1
 3    L6BEN  1  2
 4    L6BEN  5  1
 5    L6BEN  1  3
MATERI
 / 1-5 /   1
GEOMET
 3         1
 / 1 2 5 / 2
 4         3
'MATERI'
 1    YOUNG   2.0E11
      POISON  0.0
'GEOMET'
 1    INERTI  21.33333333E-8
      CROSSE  16.0E+2
 2    INERTI   0.083333333E-8
      CROSSE   1.0E+2
 3    INERTI   1.333333333E-8
      CROSSE   4.0E+2
'SUPPOR'
 / 2 4 5 / TR 1  TR 2  RO 3
   3       TR 1  TR 2
'LOADS'
CASE 1
NODAL
  7   FORCE 2 -1.0E5
ELEMEN
  3   LINE
      FORCE  -1.0E3
      DIRECT  2
'END'
```

The actual input data file is shown between two rules. The top rule may be headed with a short description at the left. The indication *file*`.dat` at the right means that the specimen shows an input data file, or a part thereof, which must have the extension `.dat`. You may choose the actual *file* name as you like; in this case we have chosen file name `frame.dat`. The tick marks on the rules indicate input fields, as we will explain later.

Basically, the input data file is subdivided in *tables*, where each table comprises a particular part of the input for the finite element model, for instance the node coordinates or the elements. Each table is denoted by a heading name of six significant letters enclosed in single quotes, for instance the first table `'COORDI'`. For your own convenience you may use more letters, like `'COORDINATES'`.

Note that some lines of text may precede the first table. This *title* may serve as an annotation of the data file. Also note that the last table of the input data file is terminated by an `'END'` line. This does not necessarily terminate the data file itself because you may put more lines of text behind it. However, DIANA will ignore all lines following the `'END'` line when reading the input data. It is not only a place to put comments, annotation etc., but also a convenient place to put data lines which are temporarily out of order. We will now describe the various input tables of this example in more detail.

3.1.1 Node Coordinates

Let us first explain how you must specify node coordinates. You should look in Volume *Analysis Procedures* of the User's Manual in which the section on 'Node Coordinates' in Chapter 1 tells you how to input node coordinates. For the two-dimensional crossed frame it could be like this:

Two-dimensional coordinates `frame.dat`

```
'COORDI' DI=2
 1    1.0  2.0
 2    5.0  2.0
 3    1.0  3.0
 4    0.0  2.0
 5    1.0  0.0
 7    0.5  2.0
```

On the first line you see the table heading `'COORDI'`. Behind the table name you see `DI=2`, this is a *parameter* indicated by a word of at most six letters, an equal sign, and a value. This particular parameter indicates the dimensionality of the model, i.e., coordinates are specified in a two-dimensional XY system. The table name and the parameter together form the *table heading*. The lines following the heading contain three values each: respectively a node number, the X coordinate, and the Y coordinate. Note that node numbers may be omitted, they may even be specified in arbitrary order.

Syntax description. The User's Manual formally describes the syntax of input table `'COORDI'` between two fat rules like this:

syntax

`'COORDI'` [`DI=`*dimens*$_n$]

1 5 6 80

node$_n$ x_r y_r [z_r]

Now what does this mean? The word *syntax* indicates that this is a formal syntax description [§ A.1.4 p. 79].[2] The typewriter style of the letters in between

[2] For styles of references in the User's Manual see § A.1.2 on page 78.

the rules indicate that it concerns the DIANA batch interface [§ A.1.1 p. 77]. In formal syntax descriptions the names, parameters etc. are typeset in capitals. However, in reality you may also type in lower case.

The notation *dimens*$_n$ in the description of parameter DI means that you must fill in a number, i.e., an unsigned whole value [§ A.1.3 p. 78]. The square brackets around the parameter indicate optionality: you may omit the parameter. However, in that case DIANA assumes that you specify the coordinates in a three-dimensional system as indicated in the margin [§ A.1.6.1 p. 82]. [DI=3]

The two thin rules below the table heading, with tiny numbers between their ends, represent the *fields* in the input data file [§ A.2.3 p. 86]. The table with node coordinates has two fields: the first from column 1 to 5, and the second from column 6 to 80. What you must specify in the fields is indicated below the bars: a *node* number somewhere in the first field and the coordinates *x*, *y*, and *z* in the second field. The subscript $_r$ means that you must type a real, i.e, a floating point value including a decimal point. Note that *z* is optional, only necessary if you apply a three-dimensional coordinate system.

3.1.2 Elements

In the batch interface, you must specify the elements in the finite element model in table 'ELEMEN' in the input data file. In the section on 'Elements' of Chapter 1 of Volume *Analysis Procedures* you may find the syntax description and some examples. For the two-dimensional crossed frame this could be like this.

frame.dat

```
'ELEMEN'
CONNEC
 1    L6BEN  4  7
 2    L6BEN  7  1
 3    L6BEN  1  2
 4    L6BEN  5  1
 5    L6BEN  1  3
MATERI
 / 1-5 /   1
GEOMET
 3         1
 / 1 2 5 / 2
 4         3
```

The table 'ELEMEN' comprises three so-called *subtables*, the first one being CONNEC with element types and connectivity. In this example we model the crossed frame with five beam elements of type L6BEN. Volume *Element Library* explains what type of elements these are, including a description of their mechanical properties and some background theory. Each L6BEN beam element is connected to two nodes, as specified behind their type names.

The second subtable MATERI assigns a set of material properties to each element. In this example all five elements, specified by a range 1-5 in between

slashes [§ A.1.5 p. 79], have the properties of material one. The last subtable is `GEOMET` which assigns a set of geometrical properties to each element. Note that elements 1, 2, and 5 have identical geometrical properties, elements 3 and 4 each have other properties. In the next section you will see how to specify the material and geometrical properties.

3.1.3 Material and Geometry Properties

In the previous section we showed how a specific set of material properties was assigned to elements via subtable `MATERI`. Now you must specify the actual properties of the material in table `'MATERI'`. DIANA supports a lot of material models, depending on the type of analysis. Volume *Material Library* formally describes their input data and background theory. For the crossed frame in this example we will perform a linear static analysis which requires the properties for linear elasticity:

frame.dat

```
'MATERI'
 1    YOUNG   2.0E11
      POISON  0.0
```

Note that `'MATERI'` is a three-field table [§ A.2.3 p. 87]: a material number in the first field, property names of six characters in the second field, and the actual values for each property in the third field. In this case `YOUNG` specifies a Young's modulus of elasticity $E = 2 \times 10^{11}$. Note the scientific notation of the floating point vale [§ A.1.3 p. 78]. The property `POISON` [*sic*] specifies a Poisson's ratio $\nu = 0$.

Like for the material properties, you must specify the geometry properties of the elements in a separate table called `'GEOMET'`. The required properties depend on the element type and therefore are formally described in Volume *Element Library*. Basically, beam elements in a two-dimensional model require a moment of inertia I_z and an area of cross-section A:

frame.dat

```
'GEOMET'
 1    INERTI  21.33333333E-8
      CROSSE  16.0E+2
 2    INERTI   0.083333333E-8
      CROSSE   1.0E+2
 3    INERTI   1.333333333E-8
      CROSSE   4.0E+2
```

Note that a number in the first field indicates the start of a new set of geometry properties.

3.1.4 Boundary Conditions

The boundary conditions for the finite element model basically define the restrictions on the degrees of freedom in the nodes. Most notably these are the *supports* which define a fixed value, usually zero, to a displacement or rotation. Other boundary conditions are the *linear constraints* or *tyings* which define linear relations between certain degrees of freedom. In the cross-frame example there are only rigid supports which you must define in table `'SUPPOR'` of the input data file. The formal description of this table is given in Chapter 2 of Volume *Analysis Procedures*. For the cross-frame example the input of the supports is as follows.

`frame.dat`

```
'SUPPOR'
 / 2 4 5 / TR 1  TR 2  RO 3
   3       TR 1  TR 2
```

A supported degree of freedom is defined by a node number, a type (translation or rotation) and a direction. In the first line of the example above you see a set of nodes, 2, 4 and 5, which all have the same support: translations in the X and Y direction, and rotation around the Z direction. Note that the set of nodes is delimited by slashes, and that the translations are indicated by `TR` and the rotations by `RO`. The directions are indicated by a number: `1`, `2`, or `3`. These numbers refer to the default set of built-in directions: X, Y, and Z respectively.

You could also specify supports in arbitrary directions with numbers greater than `4`. However, in that case you must define the actual direction in a table `'DIRECT'`, like shown below.

file`.dat`

```
'SUPPOR'
 / 2 4 5 / TR 4  TR 5  RO 3
   3       TR 1  TR 2
'DIRECT'
   4    1. 1. 0.
   5   -1. 1. 0.
```

The directions are specified by their vector components in the model XYZ coordinate system. Direction `4` points under 45° in the $+X, +Y$ quadrant and direction `5` also under 45° but in the $-X, +Y$ quadrant.

3.1.5 Loading

The loading on the finite element model is defined in table `'LOADS'`. You may specify various types of loads: nodal loads, element loads or deformations. The loads may be subdivided in *load cases*. For general syntax of load input see § 2.3 in Volume *Analysis Procedures*. For the cross-frame example there is one load case which contains a nodal load and an element load like shown below.

frame.dat

```
'LOADS'
CASE 1
NODAL
  7   FORCE 2 -1.0E5
ELEMEN
  3   LINE
      FORCE  -1.0E3
      DIRECT  2
```

The `CASE 1` line starts a new load case, with number one. Subtables `NODAL` and `ELEMEN` respectively denote the following input data to be a nodal or an element load. The nodal load is specified by a node number `7`, a type `FORCE`, a direction `2` which by default refers to the model Y direction, and a magnitude of -1×10^5, where the minus sign causes the force to act in the negative Y direction.

For the element load we have specified a distributed `LINE` load in element 3, acting along the element axis in the negative Y direction with a magnitude of 1000 per unit of length. As the input of element load depends on the type of the element, the formal syntax description of element load is described in Volume *Element Library* for each element family.

If we would have defined multiple load cases, we could have combined these into one or more *load sets* for which DIANA will calculate the analysis results. In this example we don't specify load sets and, by default, DIANA assumes a one-to-one relation between load cases and load sets. So we have a single load set number 1, which is equivalent to the specified load case 1.

3.2 Performing the Analysis

Now that the input data file has been completed, we may perform the analysis. For the cross-frame we will do a regular linear static analysis as described in Chapter 4 of Volume *Analysis Procedures*.

3.2.1 Analysis Commands

To perform the analysis you must create a command file with extension `.dcf`. A simple command file for linear static analysis is shown below.

linsta.dcf

```
*FILOS
INITIA
*INPUT
*LINSTA
BEGIN OUTPUT TABULA
 DISPLA
 STRESS LOCAL
```

```
END OUTPUT
*END
```

The commands with a star are so-called module commands, these invoke a particular module of the DIANA package. The `*FILOS` command invokes Module FILOS to maintain the FILOS file. In this case the subsequent `INITIA` command initializes a FILOS file for a new analysis. See § 3.2 in Volume *Analysis Procedures* for more information on FILOS file maintenance. The `*INPUT` command starts Module INPUT which by default reads the complete input data file. In § 3.3 of Volume *Analysis Procedures* all options of Module INPUT are described.

The actual linear static analysis is performed by Module LINSTA, invoked via the `*LINSTA` command. By default, the analysis includes all the necessary steps to set up and solve the system of equations for the finite element model. This solution basically produces the displacements of the nodes. However, by default DIANA does not give any tabular output of analysis results.

With commands in an `OUTPUT` block, delimited by the `BEGIN` and `END` keywords, you may indicate which output results you would like to see. In this case the `TABULA` option asks for output in tabular format. Furthermore, the `DISPLA` command asks for the displacements of the nodes and the `STRESS` command for the stresses in the elements. Due to the `LOCAL` option DIANA will output the stresses oriented in local element axes.

Finally, the `*END` command terminates the analysis commands. For full description of command options for Module LINSTA see Chapter 4 in Volume *Analysis Procedures*.

3.2.2 Running a Batch Analysis Job

To run a batch analysis job you must start DIANA and specify the names of the appropriate files. You must specify at least the names of the input data and command file that we just described and the name of the FILOS file, i.e., the central database for the analysis. The most simple way is to specify only a base name, like this

```
diana frame
```

Now the program `diana` is started and assumes an input data file `frame.dat`, a command file `frame.dcf`, and a FILOS file `frame.ff`, all in the current directory. All output will go to a file with base name `frame`. For this example we have batch commands on a file `linsta.dcf` and may start the analysis job like this:

```
diana frame linsta.dcf
```

When the run is terminated, the standard output file `frame.out` shows a log of the run, including any error messages or warnings that DIANA might have generated. The actual tabular output of the analysis results is on a file with extension `.tb`, in this case `frame.tb`.

We have explained the most simple way of running analysis jobs. For further options, like setting file names in environment variables, monitoring a job, types of messages etc., see Appendix B.

3.2.3 Tabular Output of Results

For the analysis job that we ran in the previous section, the tabular output file is like shown below.

`frame.tb`

```
Analysis type         LINSTA
Load case nr.         1
Result                DISPLA TOTAL  TRANSL
Axes                  GLOBAL

Nodnr       DtX        DtY        DtZ
    1   -7.949E-12 -9.234E-10  0.000E+00
    2    0.000E+00  0.000E+00  0.000E+00
    3    0.000E+00  0.000E+00  0.000E+00
    4    0.000E+00  0.000E+00  0.000E+00
    5    0.000E+00  0.000E+00  0.000E+00
    7   -3.975E-12 -3.153E+00  0.000E+00


Analysis type         LINSTA
Load case nr.         1
Result                STRESS TOTAL  CAUCHY
Axes                  LOCAL
Location of results   NODES

Elmnr Nodnr       Sxx        Sxy
    1     4   -1.590E+00 -5.023E+02
          7   -1.590E+00 -5.023E+02
    2     7   -1.590E+00  4.977E+02
          1   -1.590E+00  4.977E+02
    3     1    3.975E-01 -3.521E+00
          2    3.975E-01 -1.021E+00
    4     5   -9.234E+01 -2.271E+00
          1   -9.234E+01 -2.271E+00
    5     1    1.847E+02 -1.136E+00
          3    1.847E+02 -1.136E+00
```

Basically there are two tables of output: the displacements for the nodes and the stresses for the elements. Each table is preceded by some general information like the analysis type, the load set number, the type of result etc. Note that each column of the tables is headed by a so-called label which associates the printed values with a particular analysis result. For instance `DtY` stands for the translational displacement in the global Y direction u_Y, and `Sxx` for the Cauchy stress σ_{xx}. In § 4.2 of Volume *Analysis Procedures* you may find a description of analysis results that DIANA can output for a linear static analysis, including tables which associate an output label to a particular result item.

3.2.4 Output for Interactive Graphics Postprocessing

To get output for interactive graphics postprocessing with ¡DIANA, for instance to create pictures, you may add the `FEMVIE` output device option to the `OUTPUT`

command block, like shown below.[3]

file.dcf

```
BEGIN OUTPUT FEMVIE
 DISPLA
 STRESS
 STRAIN
END OUTPUT
```

With these commands the results are written to an ¡DIANA database with model name FRAME which may be processed interactively in the ¡DIANA Results working environment as described in § 2.5 on page 36.

[3] FEMVIE is also the default output device.

Chapter 4

Analysis of a Concrete Floor

This chapter is a further introduction to DIANA's Graphical User Interface, also known as ¡DIANA. Here we will not emphasize the more basic features as introduced in Chapter 2 but concentrate ourselves on the more advanced ones. We will discuss the application of beam elements, including special aspects of postprocessing like making a graph of a moment diagram. We will also introduce a more automatic meshing algorithm and apply a special ¡DIANA option to check the quality of the mesh. Furthermore, some general features regarding pre- and postprocessing with ¡DIANA will be shown that were not introduced earlier, for instance the application of load case combinations.

4.1 Finite Element Model

We will demonstrate the linear elastic analysis of a concrete floor of a house as shown in Figure 4.1 on the next page. The finite element model will consist of CQ24P plate bending elements for the floor and CL18B beam elements for the girder. We will concentrate on the methods for creating the model and postprocessing the results, rather than examining the results of the analysis.

4.2 Preprocessing

For this example we use the name FLOOR and enter the Design environment via the following commands.[1]

[1] The example is called cfloor and you may find the related files in the DIANA installation directory at `Examples/GetStart/cfloor`.

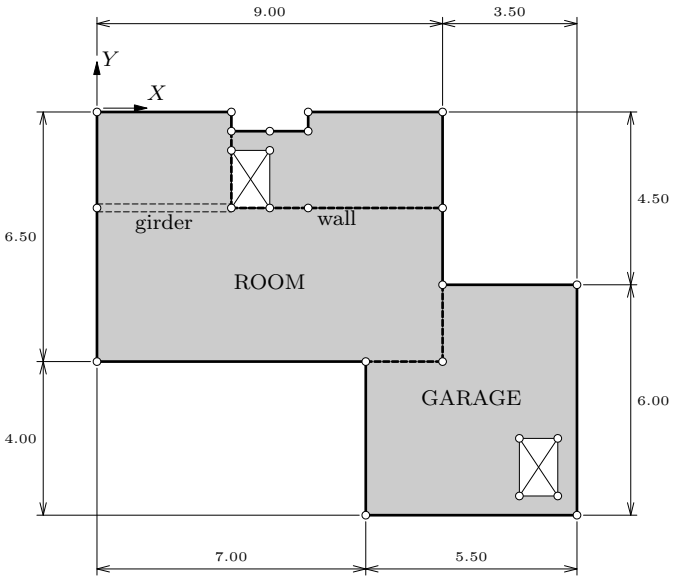


Figure 4.1: Model

FEMGEN FLOOR
... *Analysis and Units*

In the Analysis and Units dialog we indicate that this model is for three-dimensional structural analysis. Furthermore we specify that the model will be defined in SI-units [m, kg, s, K]. In this example, we will perform the various tasks to build the finite element model in the following sequence.

1. Define the geometry of the model [§ 4.2.1].
2. Generate the mesh and check its quality [§ 4.2.2].
3. Define and check the boundary constraints [§ 4.2.3].
4. Define the material and physical properties [§ 4.2.5].
5. Define and check the loading [§ 4.2.6].

In practice, task 2 can also be performed after 3, 4, and 5. In that case you should perform the checks after the meshing process.

4.2.1 Geometry Definition

Generally, in a three-dimensional model, the geometry is defined by points, lines between points, surfaces between lines, and bodies between surfaces. In

this rather simple example we will first define points [§ 4.2.1.1], and then surfaces between these points [§ 4.2.1.2]. ¡DIANA will generate the lines automatically with the surfaces

4.2.1.1 Points

As a first action in the Design environment we will create some points on the contours of the various areas of the model, indicated with ∘ in Figure 4.1. In this case it is suitable to give a number of GEOMETRY POINT commands with the coordinates in the XY axis system of each individual point.

floor.fgc

```
GEOMETRY POINT 0 0
GEOMETRY POINT 3.5 0
GEOMETRY POINT 0 -6.5
GEOMETRY POINT 7 -6.5
GEOMETRY POINT 5.5 -.5
GEOMETRY POINT 3.5 -.5
GEOMETRY POINT 7 -10.5
GEOMETRY POINT 5.5 0
GEOMETRY POINT 3.5 -2.5
GEOMETRY POINT 0 -2.5
GEOMETRY POINT 4.5 -.5
GEOMETRY POINT 4.5 -2.5
GEOMETRY POINT 5.5 -2.5
GEOMETRY POINT 9 0
GEOMETRY POINT 9 -2.5
GEOMETRY POINT 9 -4.5
GEOMETRY POINT 12.5 -4.5
GEOMETRY POINT 12.5 -10.5
GEOMETRY POINT 3.5 -1
GEOMETRY POINT 4.5 -1
GEOMETRY POINT 11 -8.5
GEOMETRY POINT 12 -8.5
GEOMETRY POINT 12 -10
GEOMETRY POINT 11 -10
GEOMETRY POINT 9 -6.5
```

Note that it is not necessary to give numbers or names to the specified points, ¡DIANA will automatically enumerate the created points: P1, P2, ⋯ etc.

floor.fgc

```
EYE FRAME
LABEL GEOMETRY POINTS
```

The EYE FRAME command automatically scales the display such that the geometry will fit in the viewport. The LABEL GEOMETRY command labels the displayed points with their names [Fig. 4.2].

4.2.1.2 Surfaces

Now we will define all surfaces with the GEOMETRY SURFACE command. First we use the 4POINTS option to define quadrilateral surfaces.

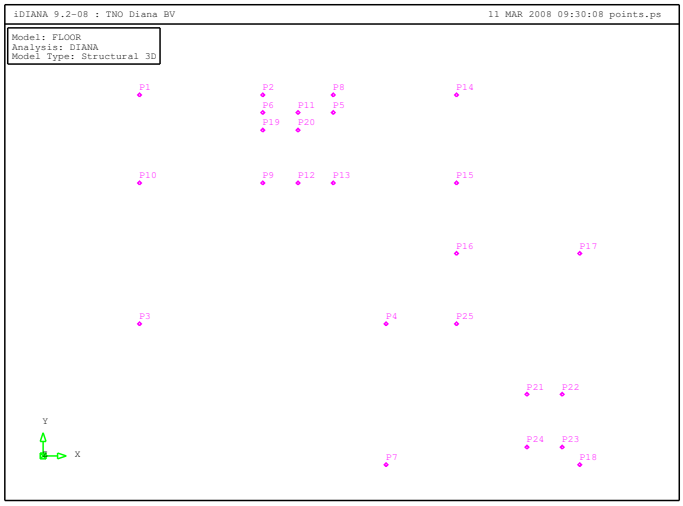


Figure 4.2: Generated points

floor.fgc

```
GEOMETRY SURFACE 4POINTS P20 P11 P6 P19
GEOMETRY SURFACE 4POINTS P13 P5 P11 +P20 P12
GEOMETRY SURFACE 4POINTS P15 P14 P8 +P5 P13
GEOMETRY SURFACE 4POINTS P9 +P19 +P6 P2 P1 P10
```

¡DIANA will automatically enumerate the four created surfaces: S1 to S4. Note the use of the plus sign to indicate midside points of so-called 'combined lines'. Next we will define the outer lines of the plate part surrounding the first staircase and simultaneously put them in a set.

floor.fgc

```
CONSTRUCT SET OPEN GARAGE
GEOMETRY LINE STRAIGHT P7 P18
GEOMETRY LINE STRAIGHT P18 P17
GEOMETRY LINE STRAIGHT P17 P16
GEOMETRY LINE STRAIGHT P16 P25
GEOMETRY LINE STRAIGHT P25 P4
GEOMETRY LINE STRAIGHT P4 P7
CONSTRUCT SET CLOSE
```

The CONSTRUCT SET OPEN command opens a set GARAGE. Then the GEOMETRY LINE STRAIGHT commands define the lines and put them in the set. The CONSTRUCT SET CLOSE command terminates the specification of lines in set GARAGE. We will now open a set HOLE for the outer lines of the staircase hole in the floor of the garage, and create the lines.

floor.fgc

```
CONSTRUCT SET OPEN HOLE
GEOMETRY LINE STRAIGHT P24 P23
GEOMETRY LINE STRAIGHT P22 P21
GEOMETRY LINE STRAIGHT P21 P24
GEOMETRY LINE STRAIGHT P23 P22
CONSTRUCT SET CLOSE
GEOMETRY SURFACE REGION S5 GARAGE HOLE
```

The command GEOMETRY SURFACE REGION creates a surface S5 for the plate around the staircase hole in the garage using the sets GARAGE and HOLE. Next we create a set named ROOM, containing the outer lines of the last part of the floor.

floor.fgc

```
CONSTRUCT SET OPEN ROOM
GEOMETRY LINE STRAIGHT P10 P3
GEOMETRY LINE STRAIGHT P3 P4
GEOMETRY LINE STRAIGHT P16 P15
GEOMETRY LINE STRAIGHT P12 P9
LABEL GEOMETRY LINES
CONSTRUCT SET APPEND LINES L25 L24 L10 L5 L15
CONSTRUCT SET CLOSE
GEOMETRY SURFACE REGION ROOM
```

We need the LABEL GEOMETRY command to display the labels for the lines that we must specify in the subsequent CONSTRUCT SET command. The GEOMETRY SURFACE REGION command creates a surface S6 for the last part of the floor using the set ROOM.

4.2.1.3 Geometry Display

We give the following commands to display and label the geometry of the model.

floor.fgc

```
VIEW GEOMETRY ALL VIOLET
LABEL GEOMETRY LINES ALL VIOLET
LABEL GEOMETRY SURFACES ALL BLUE
```

The VIEW GEOMETRY command displays the lines and points of the geometry in violet [Fig. 4.3]. Then the LABEL GEOMETRY commands will add labels for lines and surfaces.

4.2.2 Meshing

Now that the geometry has been defined completely we may continue with the meshing process. Before actually generating the mesh we specify the DIANA element type for plate elements and for the girder. Furthermore, we set the basic size of the elements and alter some of the divisions for a regular mesh. Finally we generate the mesh.

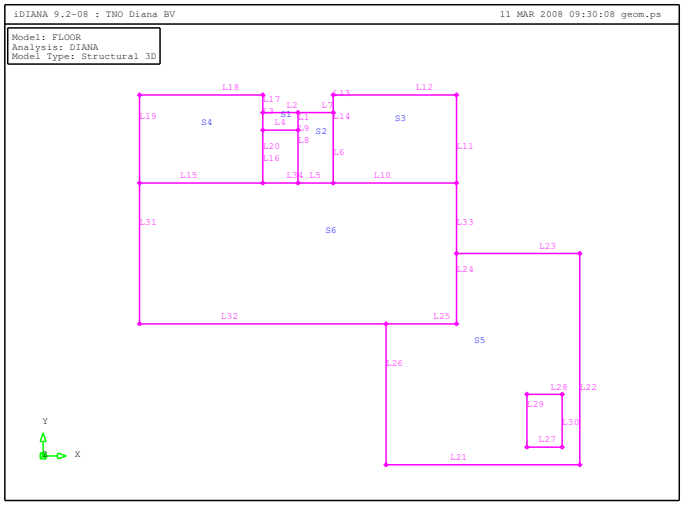


Figure 4.3: Geometry

Element types and size `floor.fgc`

```
MESHING TYPES ALL QU8 CQ24P
MESHING TYPES L15 BE3 CL18B
MESHING DIVISION ELSIZE ALL .25
MESHING DIVISION LINE L23 16
MESHING DIVISION LINE L21 24
```

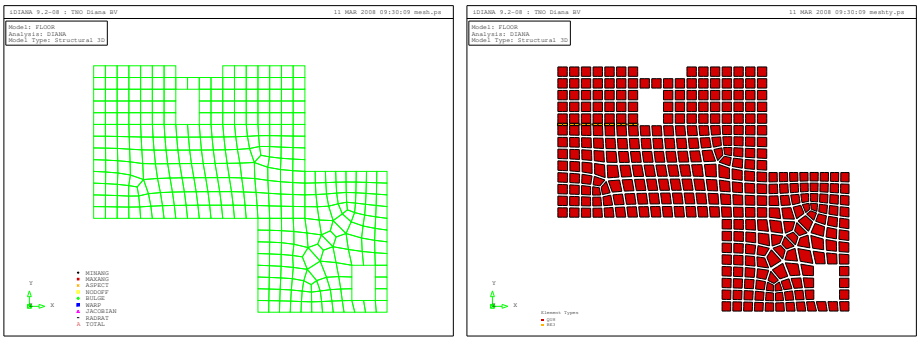
Due to the first MESHING TYPES command, all surfaces will be meshed with the generic QU8 elements. In this case we choose the CQ24P plate bending element as specific DIANA element. From the lines in the model we only assign elements to line L15 which models the girder. The generic BE3 three-node line element is mapped to the quadratic CL18B DIANA beam element.

The DIVISION option controls the number of elements that ¡DIANA will create. In this case we first specify an overall approximate size of 0.25 via the ELSIZE option and then we specify an explicit division for lines L23 and L21.

Meshing and display `floor.fgc`

```
MESHING GENERATE
VIEW MESH
LABEL MESH QUALITY
```

Due to the MESHING GENERATE command ¡DIANA will generate the mesh, but we will not get it displayed. Therefore we give the VIEW MESH command which, by default, displays the mesh in green wire netting style [Fig. 4.4a]. Due to the LABEL MESH QUALITY command ¡DIANA will label elements that fail specific



(a) wire netting style (b) color filled for element types

Figure 4.4: Generated mesh

quality tests. The appropriate labels are displayed in a legend. In this case none of the elements is labeled, so all elements satisfy the quality criteria.[2]

In the displayed mesh we don't see the beam elements of the girder, their lines coincide with the edges of the plate elements. To check if the girder is located properly in the plate we give some more VIEW commands.

floor.fgc

```
VIEW OPTIONS COLOUR TYPES
VIEW HIDDEN FILL COLOUR
VIEW OPTIONS SHRINK
```

The COLOUR TYPES option asks ¡DIANA to modulate the color of the elements according to their type. This option also requires the HIDDEN FILL COLOUR option which fills the elements with color. The SHRINK option gives a 'shrunken elements' view of the mesh which, especially in combination with color fill, is a powerful tool to check if there are any inappropriate holes in the mesh. In this case we see the QU8 elements of the floor in red and the BE3 elements of the girder in orange [Fig. 4.4b].

4.2.3 Boundary Constraints

Now that the mesh has been generated we have to define the boundary constraints (the supports). Therefore we create a set HOUSE containing all lines for the supporting walls.

floor.fgc

```
CONSTRUCT SET OPEN HOUSE
CONSTRUCT SET APPEND LINES L33 L11 L12 L13 L7 L2 L17 L18 L19 L31
```

[2] For quality criteria see the chapter on *Evaluating Mesh Quality* in Volume *Pre- and Postprocessing*.

```
CONSTRUCT SET APPEND L32
CONSTRUCT SET APPEND L3 L16 L34 L5 L10
CONSTRUCT SET CLOSE
```

The line names in the CONSTRUCT SET APPEND commands may be read from the geometry display [Fig. 4.3], or indicated with the graphics cursor. We model the walls as supports with the following commands.

floor.fgc

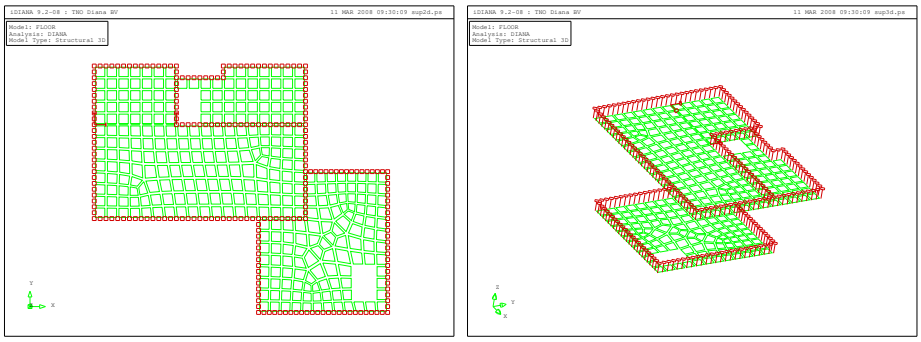
```
PROPERTY BOUNDARY CONSTRAINT GARAGE Z
PROPERTY BOUNDARY CONSTRAINT HOUSE Z
LABEL GEOMETRY POINTS
PROPERTY BOUNDARY CONSTRAINT P10 X Y
PROPERTY BOUNDARY CONSTRAINT P9 Y
LABEL GEOMETRY OFF
```

The first two PROPERTY BOUNDARY CONSTRAINT commands cause all nodes of the sets GARAGE and HOUSE to be supported in the global Z direction. The last two commands cause some points to be supported in the global X and/or Y direction. We now display the mesh including the supports.

floor.fgc

```
VIEW HIDDEN OFF
VIEW MESH
LABEL MESH CONSTRNT
EYE ROTATE TO 45 45 45
EYE FRAME
```

¡DIANA can only display labels on a non-hidden view of the mesh. Therefore we must first switch off the hidden view mode. Then the VIEW MESH and LABEL MESH CONSTRNT commands display the mesh and the supports (as nails) in a two-dimensional view [Fig. 4.5a]. To get a three-dimensional bird's-eye view of



(a) two-dimensional (b) bird's-eye view

Figure 4.5: Supports

the supports we issue an EYE ROTATE command with absolute rotation followed by an EYE FRAME command to let the model fit in the viewport [Fig. 4.5b].

4.2.4 Some More Sets

We now define some more sets to apply loads, materials, and geometrical properties and also for easy postprocessing.

floor.fgc

```
CONSTRUCT SET OPEN FLOOR1 INCOMPLETE
CONSTRUCT SET APPEND SURFACES S1 S2 S3 S6
CONSTRUCT SET CLOSE FLOOR1
CONSTRUCT SET OPEN FLOOR2 INCOMPLETE
CONSTRUCT SET APPEND SURFACES S4
CONSTRUCT SET CLOSE FLOOR2
CONSTRUCT SET GIRDER APPEND LINE L15
```

These commands create three sets: FLOOR1, FLOOR2, and GIRDER. Note the INCOMPLETE option for the sets with surfaces. Without it, the sets would not only comprise the surfaces but also the adjacent lines and points. In that case, if we put a pressure load on the set, there would be surplus loading along the meshed edges, i.e., the girder line in the set. We will now display the sets and check their contents.

floor.fgc

```
LABEL MESH OFF
VIEW OPTIONS COLOUR OFF
VIEW MESH FLOOR1 BLUE
VIEW MESH +FLOOR2 RED
VIEW MESH +GIRDER GREEN
```

We first switch off the labels and the color filling according to element type that remain from the previous sections. Then the first VIEW MESH command draws the elements in set FLOOR1 in blue [Fig. 4.6]. The subsequent VIEW MESH commands display the elements in the sets FLOOR2 and GIRDER, respectively in red and green. Note the prefix + sign which causes the elements to be superposed to the current display. Otherwise, ¡DIANA would have erased the display before drawing another set of elements.

4.2.5 Material and Physical Properties

Our next task is to define the necessary material and physical properties for the model. Therefore we call up the appropriate dialog: in the Menu Bar we choose View → Property Manager [Fig. 2.16 p. 28].

On the Materials tab we specify the material properties [Fig. 2.17 p. 28]. In the Name field we type a name for each new material. We start with CONCR for concrete. From the aspect tabs we choose Linear Elasticity. Then in the Concepts tree we choose Isotropic to define the parameters for an isotropic material. For concrete we fill in the Young's modulus parameter as 2.5E10 to define $E = 2.5\times10^{10}$. For the Poisson's ratio parameter we fill in 0.2 for $\nu = 0.2$. Then we choose the Mass aspect tab and the Mass density concept to define the Mass

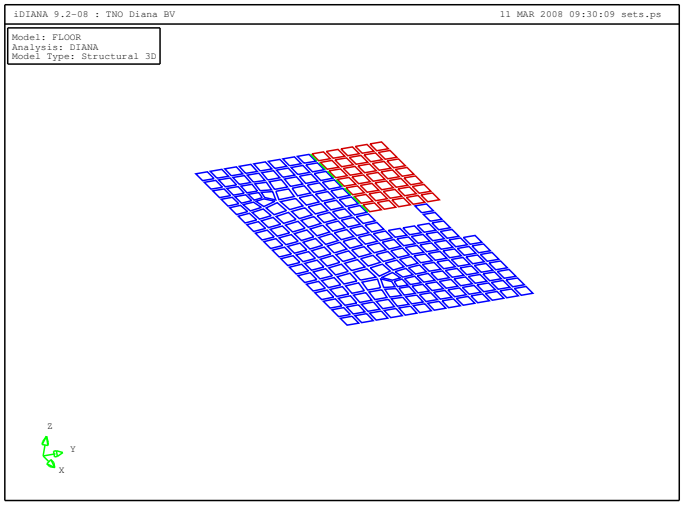


Figure 4.6: Colored sets

density parameter $\rho = 2200$. In the same way we define an other isotropic material named STEEL, for steel with $E = 21{\times}10^{10}$, $\nu = 0.3$, $\rho = 7800$.

On the Physical Properties tab we must specify properties for the plate and for the beam separately. For the plate we define a property THK where we choose the Geometry aspect and the Plate bending → Isotropic concepts to specify a thickness $t = 0.3$. For the beam we name a property IPE where we choose the Beam → Class-I → Predefined shapes → I-shape concepts to specify the dimensions of an I-shape IPE cross-section profile, with $h = 0.3$, $b_1 = 0.3$, $b_2 = 0.3$, $t_1 = 0.005$, $t_2 = 0.005$, $t_3 = 0.005$.

Now we attach the material and physical properties to the specific geometrical parts.

floor.fgc

```
PROPERTY ATTACH ALL MATERIAL CONCR
PROPERTY ATTACH GIRDER MATERIAL STEEL
PROPERTY ATTACH ALL PHYSICAL THK
PROPERTY ATTACH GIRDER PHYSICAL IPE
```

Note that we first attach concrete CONCR and thickness THK to the complete model and then overrule the attachments for the girder with specific properties STEEL and IPE.

4.2.6 Loads

To complete the model we will now apply the loads via the following PROPERTY LOADS commands.

floor.fgc

```
PROPERTY LOADS GRAVITY ALL -9.8 Z
PROPERTY LOADS PRESSURE 2 FLOOR1 -5. Z
PROPERTY LOADS PRESSURE 2 FLOOR2 -5. Z
PROPERTY LOADS PRESSURE 3 FLOOR2 -7.5 Z
```

There are three load cases. Case 1 is a GRAVITY load to the entire model, specified with an acceleration of gravity $g = 9.8$ in the $-Z$ direction. Case 2 is a PRESSURE load of $q = 5$ in the $-Z$ direction to the entire floor of the house, i.e., sets FLOOR1 and FLOOR2. Case 3 is an additional pressure load $q = 7.5$ to a part (set FLOOR2) of the floor. Note that we have excluded the girder from the sets FLOOR1 and FLOOR2 [§ 4.2.4 p. 63], otherwise the girder would have been loaded as well. We will now check the correctness of the loading.

floor.fgc

```
VIEW MESH ALL
LABEL MESH LOADS 1
LABEL MESH OFF
LABEL MESH LOADS 2
LABEL MESH OFF
LABEL MESH LOADS 3
```

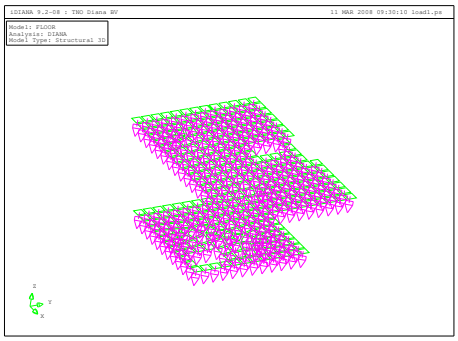
First we ask for a display of the complete mesh. Then the three LABEL MESH LOADS commands display the loads on the mesh [Fig. 4.7]. Note that before displaying a subsequent load case we have erased the previous one. Otherwise all load cases would have been displayed simultaneously.

4.3 Performing the Analysis

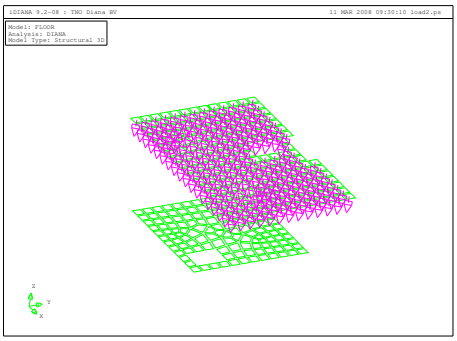
The model is completed and ready for analysis. Therefore we first write it to an input file in DIANA batch format. Then we close the model and enter the Index environment to start the analysis.

```
UTILITY WRITE DIANA floor.dat
yes
FILE CLOSE
yes
Concrete floor
ANALYSE FLOOR
```

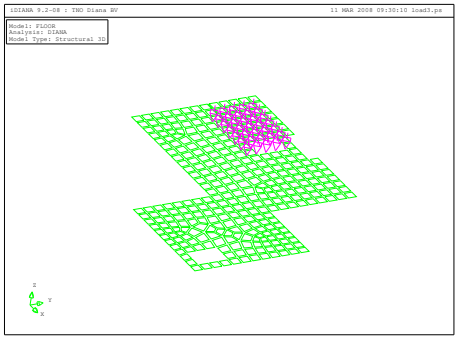
Due to the ANALYSE command the ¡DIANA Analysis Setup dialog will pop up. Here the procedure is analogous to that of the plate6 example [Fig. 2.22 p. 33]: we choose Structural linear static analysis and confirm the default file names by clicking OK.



(a) case 1



(b) case 2



(c) case 3

Figure 4.7: Load cases

4.3.1 Analysis Options

After DIANA has read and checked the input data of the finite element model the DIANA Analysis dialog appears where we may reset some options. In addition to the options for the plate6 example [§ 2.4.2 p. 33], we select the concentrated moments and forces for output, via the FORCE and MOMENT options in the Results Selection dialog [Fig. 2.25 p. 35]. These results are available for the beam elements in the girder.

The specified options are equivalent to the batch analysis comands as shown below. You may physically write a batch command file [§ 3.2.1 p. 50], and use it in subsequent jobs, by choosing File → Save in the Menu Bar of the DIANA Analysis dialog [Fig. 2.24-left].

floor.dcf

```
*FILOS
INITIA
*INPUT
*LINSTA
```

```
BEGIN OUTPUT FEMVIE BINARY
 DISPLA
 FORCE REACTI
 STRESS TOTAL MOMENT GLOBAL
 STRESS TOTAL DISMOM LOCAL
 STRESS TOTAL FORCE GLOBAL
END OUTPUT
*END
```

The BINARY option for the FEMVIE output device causes output to be written to a database for the ¡DIANA Results environment. Note the GLOBAL option which causes all analysis results to be output in the global coordinate system.

4.3.2 Running the Analysis Job

We now run the analysis job in the familiar way [§ 2.4.3 p. 36]. When the analysis job has been terminated correctly, a database FLOOR.V71 will be available in the current working directory. We will use this to do postprocessing of the analysis results with ¡DIANA.

4.4 Postprocessing

To assess the analysis results of the model we may now enter the Results environment of ¡DIANA.

floor.fvc

```
FEMVIEW FLOOR
UTILITY TABULATE LOADCASES
```

With the FEMVIEW command we enter the Results environment for the model named FLOOR. Then we give the UTILITY TABULATE LOADCASES command to get the load cases tabulated:

reslc.tb

```
;
; Model: FLOOR
;
;    LOADCASE DATA
;
;  Name         Details and results stored
;  ----         --------------------------
;
;  MODEL        STATIC  "Model Properties"
;               Element  :  THICKNES* CROSSE*
;
;  LC1          STATIC  "Load case 1"
;               Nodal    :  DTX....G  FBX....G
;               Element  :  EL.MX..G  EL.MXX.L  EL.NX..G
;
;  LC2          STATIC  "Load case 2"
;               Nodal    :  DTX....G  FBX....G
;               Element  :  EL.MX..G  EL.MXX.L  EL.NX..G
;
;  LC3          STATIC  "Load case 3"
;               Nodal    :  DTX....G  FBX....G
;               Element  :  EL.MX..G  EL.MXX.L  EL.NX..G
;  * Indicates loads data
;
```

Note that there are three load cases: named LC1, LC2, and LC3. ¡DIANA indicates which analysis results are available for postprocessing. We see nodal results: displacements (DT) and reaction forces (FB). We also see element results: bending moments (EL.M), and normal forces (EL.N). In the following sections we will show how ¡DIANA can display the analysis results in various ways.

4.4.1 Displacements

¡DIANA can present the displacements of a finite element model in various styles. We will demonstrate the most appropriate ones for this example: deformed mesh [§ 4.4.1.1], contour plots [§ 4.4.1.2], and combinations [§ 4.4.1.3].

4.4.1.1 Deformed Mesh

To display the deformed mesh we first create the familiar bird's-eye view.

floor.fvc

```
VIEW MESH
EYE ROTATE TO 45 45 45
EYE FRAME
```

These commands display the undeformed mesh in green wire netting style. To superadd a display of the deformed mesh for the gravity loading we give the following commands.

floor.fvc

```
RESULTS LOADCASE LC1
RESULTS NODAL DTX....G RESDTX
PRESENT SHAPE
```

First we select the analysis results to be displayed: the RESULTS LOADCASE command selects load case LC1 and the RESULTS NODAL command selects all components of the displacements via the RESDTX attribute, i.e., all translations. Then we give the PRESENT SHAPE command which will display the selected results as a deformed shape in red [Fig. 4.8]. The results monitor in the upper-left corner of the viewport shows which of the analysis results are currently displayed. We also see the extreme values of these results and a multiplication factor. In this case ¡DIANA has chosen a suitable multiplication of 2630× for the deformed mesh.

4.4.1.2 Contour Plots

Contour plots can only be made for scalar values, i.e., for a single component of a vector at a time. Therefore we must first select a suitable displacement component, which for this example is the vertical displacement u_Z. With the following commands we get two contour plots of u_Z in different styles.

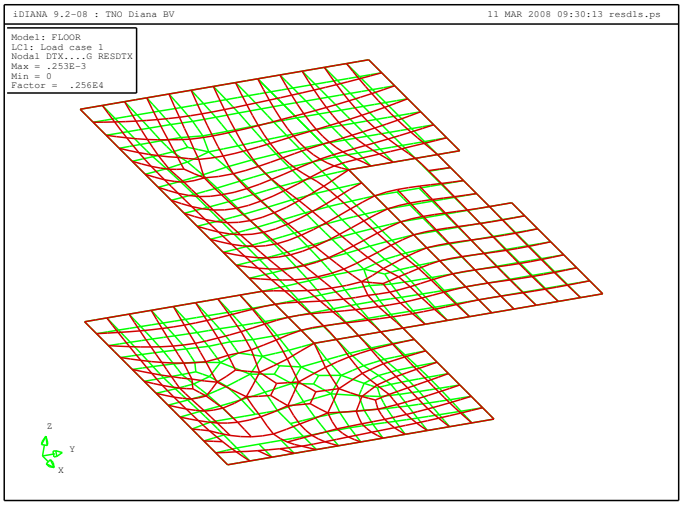
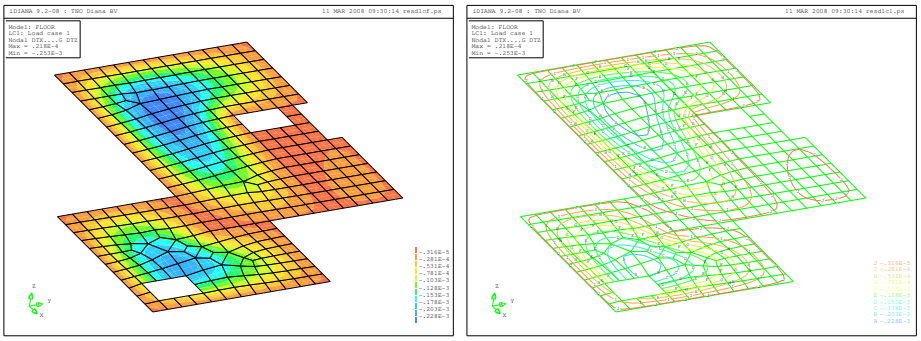


Figure 4.8: Deformation due to dead weight load

floor.fvc

```
RESULTS NODAL DTX....G DTZ
PRESENT CONTOUR LEVELS
PRESENT OPTIONS CONTOUR FILL
PRESENT OPTIONS CONTOUR LINES
```

The DTZ option selects the u_Z component of the nodal displacement vectors. Then the PRESENT CONTOUR LEVELS command asks ¡DIANA to display the contours for the selected result in ten levels by default. There are two options: FILL gives a 'filled' style, i.e., the areas between the contours are filled with a color modulated according to the value of the result [Fig. 4.9a]; LINES gives a 'line'



(a) filled style (b) line style

Figure 4.9: Contours for vertical displacement

style, i.e., the contours are drawn as lines in a color modulated according to the value of the result [Fig. 4.9b]. In both styles ¡DIANA displays a legend in the lower-right corner of the viewport which gives the value for each color.

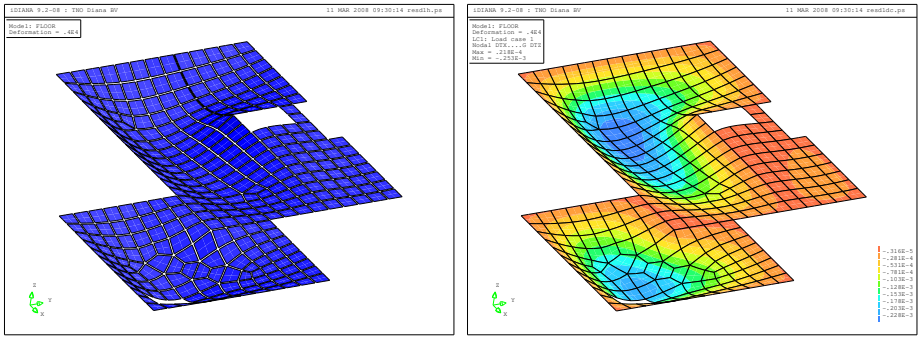
4.4.1.3 Contours on Deformed Mesh

With ¡DIANA you can also make a contour plot of an analysis result on a deformed model. In the following we will show the combination of the deformed mesh with a contour plot of the vertical displacements.

`floor.fvc`

```
VIEW OPTIONS DEFORM USING DTX....G RESDTX 4000
VIEW OPTIONS SHRINK 0.9
VIEW HIDDEN SHADE
VIEW OPTIONS SHRINK OFF
PRESENT OPTIONS CONTOUR FILL
PRESENT CONTOUR LEVELS 10
```

With the VIEW OPTIONS DEFORM USING command we indicate that the mesh must always be displayed in deformed shape according to the displacements. In this case we specify a multiplication factor 4000× to get a more pronounced deformation. With the SHRINK option we apply a shrink factor of 90 % to the elements. The VIEW HIDDEN SHADE command will fill the elements with color, shaded according to their orientation [Fig. 4.10a].



(a) shrunken hidden shade style (b) contours for vertical displacements

Figure 4.10: Deformed model

The two PRESENT commands cause the contour plot in filled style to be displayed on the deformed model [Fig. 4.10b]. Note that we do not give a RESULTS command, therefore the selected result is still the vertical displacement and the contour plot is for u_Z.

4.4.2 Load Combination

In the previous sections we have only presented results for load case LC1, the gravity load. Assume that in reality the load on the floor of the room is always present (LC3), but 1.5× as large as we specified during preprocessing [§ 4.2.6 p. 64]. Then we would like to make a combination of load cases LC1+1.5×LC3. Therefore we give the following commands.

floor.fvc

```
RESULTS CALCULATE COMBINE LCC
LC1
1
LC3
1.5
GO
Combined load
NODAL FBX....G
RESULTS CALCULATE COMBINE LCC
NODAL DTX....G
RESULTS CALCULATE COMBINE LCC
ELEMENT EL.MXX.L
RESULTS CALCULATE COMBINE LCC
ELEMENT EL.MX..G
UTILITY TABULATE LOADCASES
```

With the RESULTS CALCULATE COMBINE command we create a new load case LCC for the load combination. The individual load cases and the multiplication factors are specified in a prompt sequence which is terminated by the GO command. Then we may type a short description of the new load case. The subsequent RESULTS and NODAL/ELEMENT commands indicate which of the basic analysis results must be calculated for the new load combination. The tabulation of the load cases now also shows the contents and assembly of the combined load case:

reslcc.tb

```
;
; Model: FLOOR
;
;     LOADCASE DATA
;
;  Name         Details and results stored
;  ----         --------------------------
;
;  MODEL        STATIC  "Model Properties"
;               Element  :  THICKNES* CROSSE*
;
;  LC1          STATIC  "Load case 1"
;               Nodal    :  DTX....G  FBX....G
;               Element  :  EL.MX..G  EL.MXX.L  EL.NX..G
;
;  LC2          STATIC  "Load case 2"
;               Nodal    :  DTX....G  FBX....G
;               Element  :  EL.MX..G  EL.MXX.L  EL.NX..G
;
;  LC3          STATIC  "Load case 3"
;               Nodal    :  DTX....G  FBX....G
;               Element  :  EL.MX..G  EL.MXX.L  EL.NX..G
;
;  LCC          STATIC  "Combined load"
;               Combination: LC1 *1 LC3 *1.5
;               Nodal    :  FBX....G  DTX....G
;               Element  :  EL.MXX.L  EL.MX..G
;  * Indicates loads data
;
```

We will present analysis results for the new load combination in some of the following sections.

4.4.3 Support Reactions

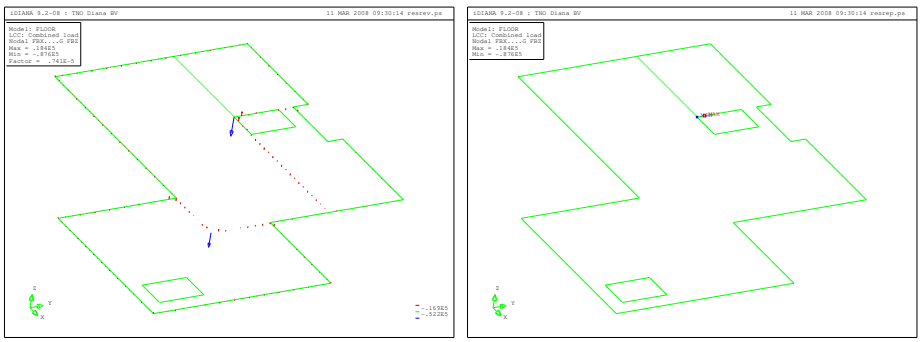
To display the support reactions for the combined load case we give the following commands.

floor.fvc

```
RESULTS LOADCASE LCC
VIEW OPTIONS DEFORM OFF
VIEW OPTIONS EDGES OUTLINE
RESULTS NODAL FBX....G FBZ
PRESENT VECTORS
PRESENT PEAKS
```

First we select load case LCC and return to an undeformed display of the model. Then the VIEW OPTIONS EDGES OUTLINE command displays the outlines, i.e., the free edges, in green [Fig. 4.11]. This style of model display is particularly useful for presentation of support reactions as these typically act at edges of the model. Next we select the nodal forces in Z direction via the FBZ component.

The PRESENT VECTORS command displays the forces in 'vector' style, i.e., arrows modulated in size and color according to the value of the force [Fig. 4.11-a]. Note that the highest reaction forces occur at the corner where the girder



(a) vectors (b) peaks

Figure 4.11: Support reactions

meets the hole in the floor of the room; their values are printed in the results monitor. The PRESENT PEAKS command indicates the location of these peak values in the model with a symbol: a red square and label MAX for the maximum and a blue cross and label MIN for the minimum [Fig. 4.11b].

Obviously, it would also have been possible to display the numerical values of the reaction forces in the model. Therefore ¡DIANA offers the PRESENT NUMERIC option which we do not demonstrate here.

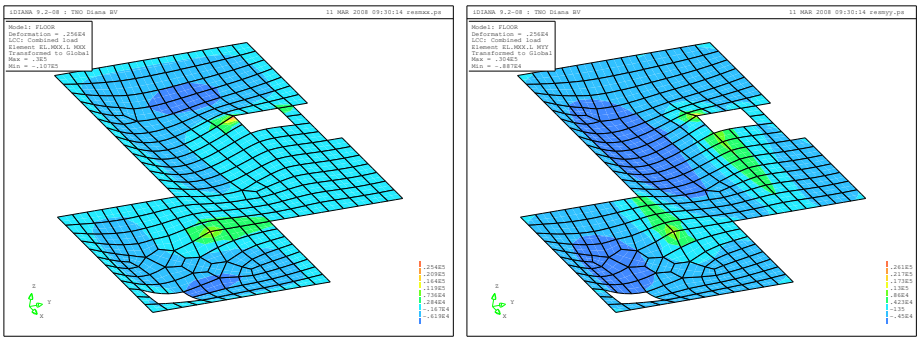
4.4.4 Bending Moments

We will now make some contour plots for the bending moments of the combined load case. We return to a deformed model and then select the appropriate results with the following commands.

floor.fvc

```
VIEW OPTIONS DEFORM USING DTX....G RESDTX
VIEW MESH
PRESENT OPTIONS CONTOUR FILL
RESULTS ELEMENT EL.MXX.L MXX
RESULTS TRANSFORM GLOBAL
PRESENT CONTOUR LEVELS 8
RESULTS ELEMENT EL.MXX.L MYY
RESULTS TRANSFORM GLOBAL
PRESENT CONTOUR LEVELS 8
```

The MXX and MYY options respectively select the m_{xx} and the m_{yy} components of the bending moments. Because we are not certain that the local x and y axes point in the same direction for all elements we give the RESULTS TRANSFORM GLOBAL command to let ¡DIANA transform the results to global XY axes. Then we ask for eight contours in filled style on the deformed model [Fig. 4.12]. Apparently the highest bending moments (red-yellow-green) occur where the curvature is large.



(a) contours for m_{XX} (b) contours for m_{YY}

Figure 4.12: Deformed model with contours

4.4.5 Moment Diagrams for Beam

Particularly for beams, it is common practice to present the analysis results as diagrams. In this example we will produce a diagram for the bending moment M_Y in the beam elements of the girder in two different styles of presentation: a diagram drawn in the display of the model [§ 4.4.5.1], and a diagram drawn as a graph with the girder axis as horizontal axis [§ 4.4.5.2].

4.4.5.1 Moment Diagram in Model Display

With the following commands we first create an appropriate display of the girder in the model and then draw a moment diagram for M_Y along the girder.

floor.fvc

```
EYE ROTATE TO 0
EYE FRAME
VIEW MESH GIRDER
EYE LOCATE
RESULTS LOADCASE LC3
RESULTS ELEMENT EL.MX..G MY
PRESENT DIAGRAM
```

The EYE ROTATE command rotates the model into a two-dimensional XY view, i.e., with the eye at $Z = \infty$. With the VIEW MESH command we display the mesh in green and the EYE LOCATE command draws the outlines of the complete model with dashed lines so that we can easily locate the part of the mesh that is displayed.

With the two RESULTS commands we select the bending moments M_Y for load case LC3 as analysis result item. Then the PRESENT DIAGRAM command draws a moment diagram in the displayed model [Fig. 4.13]. Note the color

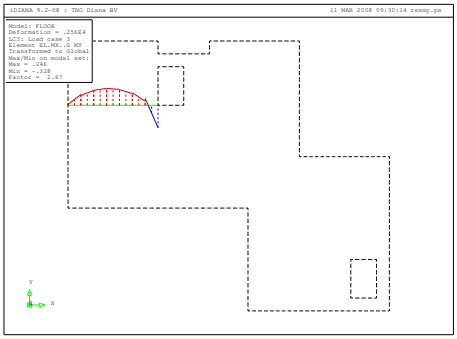


Figure 4.13: Diagram for M_Y moment in girder

modulation of the diagram: red for positive and blue for negative values. Also

note the small discontinuities in the diagram which are due to the approximative nature of the Finite Element Method. In the following section we will demonstrate how we can produce a graph of the moment diagram where these discontinuities are smoothened out.

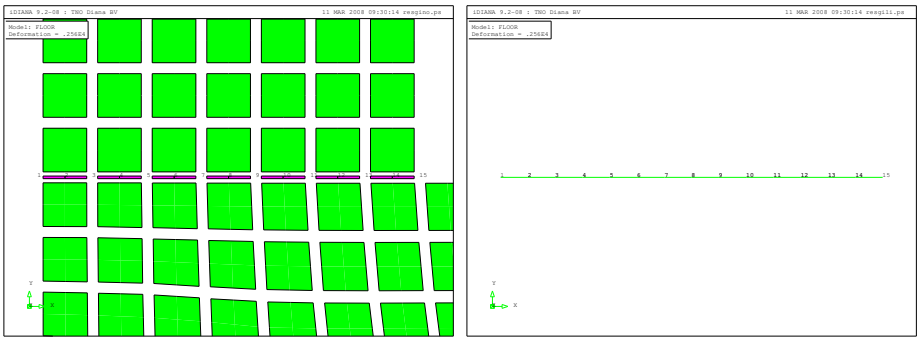
4.4.5.2 Moment Diagram as Graph

To get a smoothened graph of the bending moment M_Y in the girder we give the following commands.

floor.fvc

```
RESULTS CALCULATE AVERAGE
EYE LOCATE OFF
EYE FRAME
VIEW MESH ALL
VIEW OPTIONS SHRINK
VIEW OPTIONS HIDDEN BEAMS QUICK 30
VIEW HIDDEN SHADE
VIEW OPTIONS COLOUR TYPES
LABEL MESH NODES GIRDER
CONSTRUCT LINE NODES THROUGH 1 15
PRESENT GRAPH LINE OLD
```

First the RESULTS CALCULATE AVERAGE command averages the values of the bending moments in the nodes. Now we must define the horizontal axis of the graph by means of a line in the mesh, i.e., the girder axis. Therefore we need the end nodes of the girder which we will determine from a mesh display with node numbers [Fig. 4.14]. First the EYE FRAME command zooms in on the



(a) nodes on girder (b) line through mesh

Figure 4.14: Defining a line in the model

mesh of the girder and the VIEW MESH ALL command adds the elements of the floor that fit in the current viewport to the display. To get a clear display we apply some viewing options: SHRINK for a shrunken elements view, HIDDEN BEAMS QUICK to get the beam elements displayed as elongated squares, and

SHADE to get a shaded hidden view where the COLOR TYPES option gives color filled elements modulated according to the element type. Then the LABEL MESH NODES command labels the nodes of the girder with their numbers.

In the display we see that the end nodes of the girder are 1 and 15. Therefore we now can give the CONSTRUCT LINE NODES THROUGH command to define the line through the mesh along the girder axis. The display clearly shows that ¡DIANA has automatically determined the nodes on this line [Fig. 4.14b]. We may now give the PRESENT GRAPH command to get a graph of the bending moment diagram for M_Y in the beam elements [Fig. 4.15]. Note the blue markers

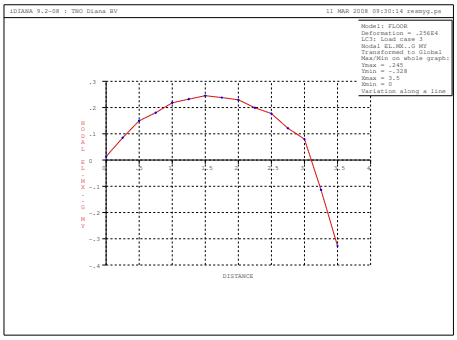


Figure 4.15: Graph of moment diagram for M_Y in girder

for the points of the graph, which represent the averaged results values in the nodes.

4.4.6 Leaving iDIANA

We now terminate this example and leave the ¡DIANA interactive session with the STOP command and confirmation.

floor.fvc

```
STOP
yes
```

Appendix A

Notation and Conventions

A.1 General Aspects

This section describes the main rules of syntax and notation in the DIANA User's Manual.

A.1.1 Fonts

Throughout the DIANA User's Manuals, various fonts (typefaces) are used to describe the syntax of input data and commands and to present examples thereof according to the following rules.

- `BATCH COMMAND`
  In formal syntax presentations and examples of the DIANA batch interface, what you type is indicated in a typewriter uppercase font.

- IDIANA COMMAND
  In formal syntax presentations and examples of the ¡DIANA Graphical User Interface, what you type is indicated in a sans serif uppercase font. See also 'Syntax' in Volume *Pre- and Postprocessing*.

  Although usually presented in uppercase, in reality you may use lowercase letters as well. In other words: the ¡DIANA and DIANA syntax is case insensitive.

- *`data item`*
  Where you have to substitute some data, slanted lowercase letters are used: in typewriter font for the batch interface or in sans serif font for the ¡DIANA Graphical User Interface.

- *annotation*
  Annotation in formal syntax descriptions and examples is printed in italics, like in "`ELEMEN` *`elems`* *element numbers*".

A.1.2 References

Various forms of reference are used, like in the following examples.

- Cross-reference to a section, figure, table or chapter in the current volume:

  '... see also §D.1.'
  '... the finite element model [§ 3.1].'
  '... as shown in Figure 3.2.'
  '... form shows up [Fig. 2.19].'
  '... series of numbers [Table A.1].'
  '..., as described in Chapter 3.'
  '... the Graphical User Interface [Ch. 2].'

  If the referred object is faraway then the reference may include the page number:

  '... material models [§ 1.1.3 p. 4].'
  '... the cross-frame example [Fig. 3.2 p. 44].'
  '... as shown in Figure 3.2 on page 44.'
  'Table B.1 on page 104 summarizes ...'

- Reference to another volume of the DIANA User's Manual:

  '... plasticity [Vol. *Material Library*].'
  '... see Chapter *Beam Elements* in Volume *Element Library*.'
  '... see 'Reinforcement' in Volume ...' refers to an index entry in the named volume.

- Reference to the Bibliography at the end of the current volume:

  '... see the book by Bathe [2].'

A.1.3 Data Types

The data type of an item to be specified in the batch interface, is indicated by a subscript in italics (like $data_n$) specifies the type of data to be substituted:

n for *number*, an unsigned whole number (without decimal point) like: `2`, `38`, `76` and `0672` .

i for *integer*, an optionally signed whole number like: `22`, `-3045`, and `021` .

r for *real*, a floating point number to be specified in 'scientific notation' like: `1.5E6`, `-18.32E-3`, `0.45E+12`, `0.36`, `-012.87`, and `27.0` . The decimal point is obligatory, the exponent and the plus sign are optional.

c for *character*, any possible single character.

w for *word*, a string of one to six significant alpha-numerical characters, the first one to be a letter like: `YOUNG`, `TIME1`, and `ELEMEN`. More characters may be typed for words with six significant characters.

s for *string*, one or more characters, if it has blanks in it to be surrounded by quotation marks. Upper and lower case letters are significant within a string. A few strings are: `Stresses`, `"Stresses case 1"`, and `Oops!@&` .

ng a letter *g* behind a number subscript means that instead of a number, a group may be specified, see 'Groups' in Volume *Analysis Procedures*.

The type specifier may be followed by a number to indicate the amount of data items to be substituted like in: $data_{n3}$ to indicate that three separate numbers must be filled in and in $type_{c2}$ to indicate that two concatenated characters must be specified. Square brackets surrounding the number mean one value or the number of values indicated in the brackets: $data_{r[4]}$ stands for one or four reals.

A.1.4 Syntax Description

Special signs, which are not a part of the actual input, are used in formal syntax descriptions:

... Ellipses indicate repetition: $data_{n...}$ stands for one or more numbers.

[ ] Square brackets indicate optionality of what is inside: it may be omitted.

{ } Braces indicate a choice out of what is inside them.

> *In input or commands, items must be separated by one or more spaces which are not explicitly mentioned in the syntax descriptions.*

A.1.5 Series of Numerical Values

In the batch interface, series of numbers, integers or reals may be input in compressed form, with the aid of the characters `-`, `:`, `(`, and `)`. These characters are part of the input and may *not* be separated by spaces from the data.

Apart from the characters mentioned above, the slash character `/` is often used to mark the beginning or termination of a series of values. This slash is part of the input and must be separated from the values, words etc. by one or more spaces.

Range of values	*syntax*
init`-`*limit*[`(`*increm*`)`]	
init`:`*limit*[`(`*increm*`)`]	

A range is specified by an initial value *init*, a limit value *limit* in parentheses. Initial value, limit value and increment must be of the same type, by default the increment is equal to one. For *integer* or *real* ranges, the sign of the increment must conform the difference of limit and initial value, in other words: "If *limit* > *init* then *increm* > 0 else *increm* < 0".

> *If you want to be sure that the* `limit` *of a real range becomes part of the series, then it is safe to specify it a bit greater than the* `init` *plus a multiple of* `increm`*. This is to avoid that the limit value is excluded due to round-off errors in comparisons of floating point values.*

Equal values *syntax*

val (*rep* $_n$)

Input of a series of equal values, may be done in abbreviated form: a value *val* followed by a number *rep* in parentheses indicates how many times the value must be repeated. Table A.1 presents some examples of input of series of numbers.

Table A.1: Series of numbers

Input	Represents the same as
`12-18(2)`	`12 14 16 18`
`6-13(3) 22 54-57`	`6 9 12 22 54 55 56 57`
`19-27(2) /`	`19 21 23 25 27 /`
`-12:6(4)`	`-12 -8 -4 0 4`
`3.6:-9.2(-4.1)`	`3.6 -0.5 -4.6 -8.7`
`5 6(4)`	`5 6 6 6 6`
`52-60(3) 65(4) 90-94`	`52 55 58 65 65 65 65 90 91 92 93 94`

A.1.6 Presentation of Syntax and Examples

Throughout the Diana User's Manual, syntax and examples will be presented formally, but:

> *Whenever there is a contradiction between a formal syntax description and an example, the syntax description is presumed to present the truth.*

The styles for formal presentation are as follows.

Formal syntax *syntax*

`*INPUT`
[`READ` { _____ }] [`FILE=`*infil* $_s$] [`TABLE` *tabnam* $_{w...}$]]

```
        ECHO
        APPEND
[ DELETE TABLE tabnam_w... ]
[ REMAKE [FILE=outfil_s] [TABLE tabnam_w...] ]
```

Formal syntax descriptions are presented between two rules. The top rule is headed by an optional title and the word *syntax*.

Examples. Examples of input data, commands and output are displayed between two rules. The top rule may be headed by a short title.

Input data *file*.dat

```
'COORDI'
  1   22.5  36.8  -24.54
  2   12.2  99.34 -25.60
```

Examples of input data are headed by a filename with extension `.dat`.

Analysis commands *file*.dcf

```
*INPUT
*LINSTA
BEGIN OUTPUT
 DISPLA
END OUTPUT
*END
```

Examples of analysis commands are headed by a filename with extension `.dcf`.

Standard output *file*.out

```
/DIANA/EI/EV
         4 EIGENVALUES FOUND AFTER    5 ITERATIONS
    EIGEN-FREQUENCIES (HZ) :
    .91583D+00(  1)     .57398D+01(  2)     .16154D+02(  3)     .32187D+02(  4)
```

Examples of DIANA's standard output file, or parts thereof, are headed by a filename with extension `.out`.

Tabular output *file*.tb

```
Analysis type         LINSTA
Load case nr.         3
Result                DISPLA TOTAL  TRANSL
Axes                  GLOBAL

Nodnr       DtX        DtY        DtZ
    1    4.016E-05  0.000E+00  0.000E+00
    2    8.021E-05  0.000E+00  0.000E+00
    3    9.012E-05  7.249E-07  0.000E+00
```

Examples of DIANA's tabular output file, or parts thereof, are headed by a filename with extension `.tb`.

A.1.6.1 Optionality and Defaults

Square brackets [ ] around something in a formal syntax description indicate that this 'something' is optional, you may leave it out:

Optionality *syntax*

PERFOR [MI=*maxit*$_n$]

This means that you may type the command PERFOR without anything else. Like this:

file.dcf

```
PERFOR
```

[MI=10] In this case a default value of what you did not type is indicated in the margin enclosed in square brackets as shown here, which means that the variable *maxit* will have the value of 10 if you don't specify it.

Optional block *syntax*

```
*LINSTA
[ BEGIN OUTPUT
  ...                    output selection
 END OUTPUT ]
```

If a pair of brackets balances over more than one line, the enclosed lines form an optional block. Like in the example above, this means that the whole output selection is optional, the explanation underneath the syntax description tells what happens if you omit these commands.

A.1.6.2 Menus

The possibility to choose out of many things, is indicated with a 'menu line', you may choose out of the things listed below the line. There are three types of choice: unique, optional and multiple.

Menu unique choice *syntax*

```
PERFOR _____
       LINEAR
       CONSTA
       NEWTON
```

In this case you *must* choose one of the keywords LINEAR, CONSTA or NEWTON.

file.dcf

```
PERFOR LINEAR        or:
PERFOR CONSTA        or:
PERFOR NEWTON
```

Menu optional choice *syntax*

```
NEWTON [______]
        MODIFI
        REGULA
```

A menu line surrounded by square brackets [ ] means that you *may* choose one of the things listed below the line, you may even choose 'nothing'. In the example above you may choose one of the keywords `MODIFI` or `REGULA` but not both. The default choice is explained below the syntax description.

file.dcf

```
NEWTON MODIFI        or:
NEWTON REGULA        or:
NEWTON
```

Menu multiple choice *syntax*

```
STRESS {______}
        CAUCHY
        GENERA
```

A menu line surrounded by braces { } means that you may choose more than one of the things listed below the line, you may even choose 'nothing'. In the above case you could type either one of the following commands:

file.dcf

```
STRESS CAUCHY             or:
STRESS GENERA             or:
STRESS CAUCHY GENERA      or:
STRESS
```

If only the command `STRESS` is specified, DIANA makes a default choice which again is explained below the syntax description.

Nested menus *syntax*

```
PERFOR ______          [MI=maxit_n]
       LINEAR
       CONSTA
       NEWTON[______]
              MODIFI
              REGULA
```

Menus can also be nested, like in the example above.

A.1.6.3 Repetition

Ellipses '...' are used in a syntax description to show that the previous thing(s) may be repeated. This applies for data as well as for complete lines.

Repetition of variables *syntax*

```
NODES nodnrs_n...
```

This means that the variable ***nodnrs*** consists of one or more numbers for example:

file.dcf

```
NODES 12 17 19 31
```

Repetition of line *syntax*

```
STOP ______          ...
     TOTAL  totlod_r
     INCREM inclod_r
     SIGN
```

This means that the complete STOP command may be specified more than once in one command file, for instance like:

file.dcf

```
STOP TOTAL 1.2
STOP SIGN
```

A.2 Batch Input Data Format

The DIANA batch input data file is subdivided vertically in an optional *title* section followed by *tables*, and horizontally in *fields*. See also § A.1 on page 77 for general rules of syntax and notation.

A.2.1 Title

Before the actual input data, a *title* can be placed as an identification for the analysis. This title may consist of an arbitrary number of lines of text, for example, the name of the project, the principal, the date, etc.

The title is printed at the beginning of every DIANA output file. The first line of the title has a special status, it will be printed above every page of tabular output.

A.2.2 Tables

Each table has a name of which only the first six letters are significant. For example: `COORDI` and `COORDINATES` are both correct names for a table with nodal coordinates. The name of the table is given between single quotes and on a separate line, the *heading* line. The first quote must be in column one of the input file. An example of a heading line is:

file.dat

```
'COORDI'
```

The heading line precedes the actual data. Sometimes one or more *parameters* can follow the name of the table. These consist of two letters, followed by an `=` sign, after which the value of the parameter must follow. A typical example of a parameter is the specification of the dimensions of a table such as:

file.dat

```
'COORDI' DI=2
```

This indicates that these are coordinates in a two-dimensional coordinate system. Most of the parameters for tables are optional, if they are left out, DIANA will assume a reasonable default value. This default value is indicated in the explanation following the formal syntax description of the table.

Tables may be in the input file in a random order; however, the last table should be closed with the line:

syntax

```
'END'
```

This line also indicates the end of the applicable input. After this `'END'`-line, parts of input which are no longer or not yet applicable can be 'parked'.

A.2.2.1 Subtables

Some tables may be subdivided in subtables, for instance table 'LOADS' may contain NODAL loads and ELEMENT loads. The heading of a subtable consists of at most six significant letters, the first of which must be in column 1, like this:

file.dat

```
'LOADS'
ELEMEN
        element load data
NODAL
        nodal load data
```

A.2.3 Fields and Data

A data line in the input file is usually subdivided into fields. Each field consists of a number of positions (columns). The syntax of the tables is *semi-format free*; that is to say, the data should start in a certain field of the input line, but after this condition has been met, they may be placed at will within that field. With respect to the number of fields, there are three types of tables: one-field, two-field and three-field.

One-field table *syntax*

```
1                                                                              80
```

The field ranges from column 1 to 80. The data may be positioned anywhere on the data line. An example of a one-field table is table 'INIVAR' to input initial nodal potentials in a potential flow analysis [Vol. *Analysis Procedures*].

file.dat

```
'INIVAR'
POTENT 3
  1  0.001
 / 4 7 10-30(5) / 0.00005
 / 34 37 40-70(5) / / 0.001(2) 0.0005(7) /
```

Note that in examples of input data, field delimiters are always displayed for a three-field table.

Two-field table *syntax*

```
1        5 6                                                                80
```

The first field ranges from column 1 to 5 and usually contains a number, for example a node number. The second field ranges from column 6 to 80 and contains the actual data like the nodal coordinates:

file.dat

```
'COORDI'
  1  0.10  0.08  0.38
  2
     0.80  0.08  0.36
  3  0.65  0.53  1.45
  4  0.21  0.46  -0.12
  1036  10.56  -12.45  38.66
```

Note that the coordinates of a node may be placed on a separate line (see node 2) as long as they start in the second field. Note also that a data item (see node number 1036) may pass along the field terminator column as long as it starts in its proper field.

Three-field table *syntax*

```
1        5 6           12 13                                                80
```

The first field ranges from column 1 to 5 and again usually contains a number, for example an element number. The second field ranges from 6 to 12 and often contains a name, like the element type. The third field ranges from 13 to 80 and contains the actual data like the node numbers. The following illustrates different ways of input of the same element.

file.dat

```
   1  CHX60    1 4 6 8 10 12 14 18 20 22 26 30 31 57 64 5 9 17 25 36
   1  CHX60    1 4 6 8 10 12 14 18 20 22
               26 30 31 57 64 5 9 17 25 36
   1  CHX60    1 4 6 8 10 12 14 18
               20 22 26 30
               31 57 64 5 9 17 25 36
   1
      CHX60    1 4 6 8 10 12 14 18
               20 22 26 30
               31 57 64 5 9 17 25 36
```

```
   1
      CHX60
              1 4 6 8 10 12 14 18 20 22 26 30 31 57 64 5 9 17 25 36
```

Note that data in the third field may be distributed over several lines, on condition that they are placed in the corresponding field.

DIANA *can read up to 10000 values in a data record.*

A.2.4 Comment and Blank Lines

You may put comment lines, that will not be interpreted by DIANA, anywhere in the input file with a colon in column one:

Comment *file*.dat

```
: units kg, m, s, Pa
'MATERI'
:                       PVC
  1   YOUNG     3.0E+9
      POISON    0.4
      DENSIT    1.3E+3
      THERMX   50.0E-6
:                       Steel
  2   YOUNG   200.0E+9
      POISON    0.3
      DENSIT    7.8E+3
      THERMX   12.0E-6
```

You can, of course, also put a colon in column one to inactivate input lines. Blank lines may be inserted anywhere in the input file to improve readability:

Blank lines *file*.dat

```
'MATERI'

  1  YOUNG   3.0E9
     POISON  0.42
     DENSIT  1.3E3
     THERMX  50.0E-6

  2  YOUNG   200.0E9
     POISON  0.3
     DENSIT  7.8E3
     THERMX  12.0E-6
```

A.2.5 Examples

Following examples of input data files serve merely to illustrate the syntax of input data, and not to show input for actual finite element models.[1]

file.dat

```
BEAM FOR DYNAMIC ANALYSIS
'COORDI'
   1   0.  0.  0.
   2   2.  0.  0.
   3   4.  0.  0.
   4   6.  0.  0.
   5   8.  0.  0.
'ELEMENT'
CONNECTIVITY
   1 L6BEN  1 2
   2 L6BEN  2 3
   3 L6BEN  3 4
   4 L6BEN  4 5
MATERI
 / 1-4 / 1
GEOMETRY
 / 1-4 / 1
'MATERI'
   1 YOUNG 10.E9
     DENSIT 2500.
'GEOMETRY'
   1 CROSSE  0.080
     INERTI  0.001066667
'DIRECTIONS'
   1  1.  0.  0.
   2  0.  1.  0.
'SUPPORT'
 / 1 5 / TR 2
 / 3 /   TR 1
'LOADS'
CASE  1
WEIGHT
   2   10.
'END'
```

file.dat

```
Wall with square gap, spring supports.
Load set 1: dead weight          rho=2400 kg/m3.
Load set 2: vertical load:         q=1.000N/mm1.
```

[1] For realistic examples see § 3.1 on page 44 and Volume *Analysis Examples*.

```
Load set 3: horizontal wind load:  p=0.500N/mm1.
'COORDINATES'
    1       0.000   -3000.000       0.000
    2     600.000   -3000.000       0.000
    3    1200.000   -3000.000       0.000
    4    1800.000   -3000.000       0.000
    5    2400.000   -3000.000       0.000
                                              nodes 6-105 omitted
  106    6000.000    2800.000       0.000
  107    6000.000   -1000.000       0.000
  108    6000.000   -2000.000       0.000
  109    6000.000   -3000.000       0.000
'ELEMENTS'
CONNECTIVITY
    1 CQ16M     1    2    3    9   14   13   12    8
    2 CQ16M     3    4    5   10   16   15   14    9
    3 CQ16M     5    6    7   11   18   17   16   10
    4 CQ16M    12   13   14   20   25   24   23   19
                                              elements 5-25 omitted
   26 CQ16M    93   94   95   99  104  103  102   98
   27 CQ16M    95   96   97  100  106  105  104   99
   28 L12BE    57  107
   29 L12BE   107  108
   30 L12BE   108  109
   31 SP1TR     1
   32 SP1TR     3
   33 SP1TR     5
   34 SP1TR     7
MATERIALS
 /    1-9 /    1
 /   10-12 /    2
 /   13-15 /    2
 /   16-21 /    2
 /   22-27 /    2
 /   28-30 /    1
 /   31-34 /    3
GEOMETRY
 /  1-9  /    1
 / 10-27 /    2
 / 28-30 /    3
 / 31-34 /    4
DATA
 /  1-27 /    1
'MATERIALS'
   1 YOUNG     25000.
     POISON     0.200
     DENSIT     2.500E-06
   2 YOUNG     20000.
     POISON     0.200
```

```
     DENSIT     2.400E-06
   3 SPRING    10000.

'GEOMETRY'
   1 THICK       250.
     XAXIS    1.   0.   0.
   2 THICK       200.
     XAXIS    1.   0.   0.
   3 YAXIS    0.   0.   1.
     CROSSE    0.100E+06
     INERTI    1.333E+09  0.520E+09    1.
   4 AXIS     0.  -1.   0.
'DATA'
   1 NGAUS    2   2
'DIRECTION'
   1    1.   0.   0.
   2    0.   1.   0.
   3    0.   0.   1.
'SUPPORTS'
 /   7 /   TR 1
 / 109 /   TR 1 2 3  RO 1 2
'TYINGS'
BETWEEN TR 1 2
 16  15 17
'LOADS'
CASE  1
WEIGHT
   2     -10.
CASE  2
ELEMEN
 / 10-16 /
      EDGE    ETA1
      FORCE  -1.000
      DIRECT     2
 / 19-21, 25-27 /
      EDGE    ETA2
      FORCE  -0.800
      DIRECT     2
CASE  3
ELEMEN
 /  1-10(3), 16, 19 /
      EDGE   KSI1
      FORCE  +0.500
      DIRECT    1
'END'
```

A.3 Batch Command Language

As a user you must tell DIANA what to do with the finite element model on the input file. In the batch interface you do this with analysis commands. This section first presents the rules of grammar and syntax of the DIANA Command Language followed by some examples of actual command sets for various types of analysis. See also § A.1 on page 77 for general rules of syntax and notation.

The DIANA Command Language consists of *keywords*, *data items* and *parameters*, mutually separated by one or more spaces. Special commands are used to group commands together for DIANA modules and to terminate the command file. Moreover there are rules for comment and blank lines.

A.3.1 Keywords

Keywords are terms (usually verbs or nouns) derived from engineering practice or data processing like `STRESS` and `OUTPUT`. Keywords are of data type *word* hence `STRESS`, `STRESSES` and `stress` represent the same keyword.

A.3.2 Data Items

A data item is any data, for instance a number, to be filled in by the user. Data items may have either one of the types mentioned in § A.1.3 on page 78 and appear in syntax descriptions like *name*$_n$ for a *number*. In explanations the data item usually appears like *name*, the data type is omitted.

A.3.3 Parameters

A parameter is a named variable, mostly a number, specified as part of a command. It consists of two parts, separated by an equals sign: a name on the left and a value on the right, for example:

file.dcf

```
SUBSPA ECONVE=1.2E-6
```

In this case the parameter `ECONVE` gets the value of 1.2×10^{-6}. Spaces are allowed around the equals sign.

A.3.4 Module and Control Commands

From the user's point of view, the DIANA package is subdivided in modules [§ 1.2 p. 6]. A specific module is activated with a so-called 'module command'.

Module commands. A module command starts with a star `*` in column one, immediately followed by the module name.

file.dcf

```
*LINSTA
*NONLIN
```

Control commands. The first occurrence of a module command may be preceded by control commands [Vol. *Analysis Procedures*]. These commands control general aspects of the DIANA run, like the appearance of log lines, the maximum number of fatal errors and the maximum number of warnings to be printed.

file.dcf

```
NOLOG
ERRORS MF=30 MW=2
```

Control commands are only specified to overrule the defaults.

Default commands. Unlike control commands, there are no default module commands. The modules must be invoked in a sequence which follows from their function in the Finite Element Analysis process. For an example of module commands for linear static analysis see § A.3.8.

Many modules have a set of default commands which are invoked if the user only specifies the module command. The set of default commands is usually indicated in the explanation or in an example. If not indicated, there are no default commands.

Command sequence. The sequence of the commands within the module is obligatory as presented in the formal syntax description.

Termination command	*syntax*
`*END`	

The commands must be terminated with an `*END` line. DIANA will skip the lines behind the `*END` so this is the place to hide temporarily inactive commands.

A.3.5 Continuation of Commands

A backslash indicates that the command continues on the next line. A typical application is a command with a large series of numbers.

file.dcf

```
*LINSTA
BEGIN OUTPUT
 BEGIN SELECT
  NODES 2-20(2) 49 12 27 38 45 63 99 112 116 138-142 154 183 185 \
        220-250(3) 287 412 525
 END SELECT
END OUTPUT
```

A.3.6 Command Blocks

Typically commands are grouped in named blocks, starting with '`BEGIN` *name*' and terminated by '`END` *name*'. The syntax description is like this.

syntax

```
BEGIN EVALUA
[ OFF ]
[ CHECK { ______________ } ]
         SHAPE=eshape_r
         RATIO=eratio_r
[ REINFO INTERF [ ___ ] ]
                 ON
                 OFF
[ COMPOS ]
END EVALUA
```

The underlined BEGIN and END keywords indicate that you may abbreviate the command block to single commands by omitting the `BEGIN` keyword and the complete `END` line. According to this syntax you may type in full:

file.dcf

```
BEGIN EVALUA
 CHECK SHAPE=1.E-4 RATIO=2.5
END EVALUA
```

Alternatively you may type in short:

file.dcf

```
EVALUA CHECK SHAPE=1.E-4 RATIO=2.5
```

Note that in short format, an indeterminate number of values for a parameter or a series of data must be terminated by a slash '`/`'.

A.3.7 Comment and Blank Lines

You may put comment lines, that will not be interpreted by DIANA, anywhere in the command file with a colon in column one:

Comment *file*.dcf

```
*LINSTA
:evaluate elements
EVALUA CHECK SHAPE=0.002
```

You can, of course, also put a colon in column one to inactivate commands. Blank lines may be inserted anywhere in the command file to improve readability:

Blank lines *file*.dcf

```
: read input data
*INPUT

: evaluate and assemble elements
*LINSTA
EVALUA
ASSEMB
```

A.3.8 Example

This section presents an example of commands for linear static analysis to illustrate the syntax of the DIANA Command Language.

Linear static analysis *file*.dcf

```
*FILOS
INITIALIZE
*INPUT
*LINSTA
BEGIN OUTPUT
 DISPLA
 STRESS
END OUTPUT
*END
```

`*FILOS` Module FILOS is used to maintain the FILOS file, the central database for each analysis with DIANA [§ 1.2 p. 6].

`INITIA` In this example the FILOS file is initialized in the analysis run, with a default maximum size.

`*INPUT` Module INPUT reads the complete input data file.

`*LINSTA` Module LINSTA performs a complete linear static analysis of the finite element model.

`OUTPUT` The commands in this block produce output of linear static analysis results [Vol. *Analysis Procedures*]. In this case we ask for displacements and stresses for all nodes and elements. By default the output is produced in *tabular* form

To get a *picture* of the analysis results, you may specify the `IDIANA` output device and visualize the model and the analysis results with ¡DIANA [Vol. *Pre- and Postprocessing*].

`*END` This line indicates the end of the commands; comment or inactive commands may follow it.

See also Chapter 3 for more examples of commands.

Appendix B

Running a Batch Analysis Job

This chapter formally describes the procedure of running a batch analysis job. See also § 3.2.2 on page 51 for an instructive example.

B.1 Running DIANA

This section first describes the general aspects of running a DIANA job in the batch interface which are more or less the same on every operating system. The two final sections outline the peculiarities for a particular operating system: §B.1.5 for UNIX, and §B.1.6 for Windows.

B.1.1 Files

DIANA uses various types of files in a job. Each of the file types has a unique extension to its base name (a period and some characters) as indicated in the following.

Input file. The input data file describes the finite element model. It contains tables of input data. See § A.2 on page 85 for general syntax, and Volume *Analysis Procedures* for input description for specific types of analysis. [.dat]

Command file. The command file describes how to analyze the model and what output to produce. See § A.3 on page 92 for general syntax, and Volume *Analysis Procedures* for command description for specific types of analysis. [.dcf]

Output files. These files are created by DIANA during a job. There are various types of output files:

Standard output, contains information about the performance of the job such as error messages [§ B.1.3] and log information about usage of CPU time [§ B.1.4]. [.out]

[.tb] *Tabular output,* contains the tabulated results of the DIANA run, such as displacements, strains and stresses. Tabular output is created due to the `OUTPUT TABULA` commands.

¡DIANA *postprocessing output,* on files for interactive graphics postprocessing with ¡DIANA [Vol. *Pre- and Postprocessing*]. This output is created due to the `OUTPUT FEMVIE` commands. For DIANA-9.3 the extensions are `.V71` and `.M71` for binary format, and `.fvi` for ASCII format.

FX$^+$ *postprocessing output,* on files for interactive graphics postprocessing with FX$^+$ [Vol. *FX+ for DIANA*]. This output is created due to the `OUTPUT FXPLUS` commands. For DIANA-9.3 the extensions are `.dpb` and `.dmb` for binary format, and `.dpa` and `.dma` for ASCII format.

[.ff] **FILOS file.** The FILOS file is the central database for each analysis project. It is maintained through Module FILOS [§ 1.2 p. 6].

[.sys] **System file.** The system file lists the actual file names assigned to the job. If by any chance the computer system produces messages like "disc full," "CPU time limit" etc., these will appear on the system file as well.

B.1.2 Running a Job

To run a DIANA job you must start its control system which has the name `diana`. The start `diana` command has some optional arguments, mainly to specify file names that must be used or created during the execution of the job.

B.1.2.1 Tutorial

The most usual way to start a DIANA job is with a base name for files:

```
diana plate
```

This job uses input file `plate.dat`, command file `plate.dcf` and FILOS file `diana.ff`. Error messages and log information will be on `plate.out` and tabular output of postanalysis results on `plate.tb`. If you would like to specify the FILOS file explicitly, for instance because you use various FILOS files in the same working directory, then the command to start DIANA could be

```
diana plate joseph.ff
```

This job is analogous to the previous one, except that the FILOS file is `joseph.ff`. If you prefer not to have the FILOS file in the current working directory then it is useful to set its name in the environment symbol `FF`, like in the following example (for the UNIX C shell)

```
setenv FF /usr/tmp/joseph.ff
diana plate
```

This job is analogous to the previous one, except that the FILOS file is now located in directory `/usr/tmp`. If you want to use the same input file with various command files, then the following could be a useful run command.

```
diana plate linear.dcf
```

This job uses `plate.dat` as input file and `linear.dcf` as command file. The base name of output files will be `plate`: tabular output on `plate.tb`. To use the same set of output files you could run jobs like this:

```
diana result plate.dat linear.dcf
```

This job uses `plate.dat` as input file and `linear.dcf` as command file. The base name of output files will be `result`: tabular output `result.tb`. Finally you may also start DIANA without file name specification:

```
diana
```

This job uses default names for files: `diana.dat` for the input file, `diana.dcf` for the command file and `diana.ff` for the FILOS file. Error messages and log information will be on `diana.out` and tabular output of postanalysis results on `diana.tb`.

B.1.2.2 Reference

The general form of the command to start a DIANA run on a computer system is as follows.

syntax

`diana` [`-m`] [*basename*] [*file*`.dat`] [*file*`.dcf`] [*file*`.ff`]

`diana` starts the DIANA control system.

`-m` causes monitoring of the job if it runs in the foreground, i.e., DIANA shows on the terminal screen what is going on. For example:

```
 /DIANA/AP/LS41    16:37:02      0.14-CPU     0.15-IO      99.-FA   BEGIN
                    5 EVALUATING ELEMENTDATA
                    5 CREATING ELEMENTBASES
                   20 EVALUATING SUPPORTS
```

This means that Segment `AP/LS41`, the 'Application for Linear Static analysis – version 41', is evaluating the element data; there are 5 elements evaluated; creating the element bases; there are 5 elements bases created; evaluating the supports; there are 20 supports evaluated. In this way you can see how fast everything is progressing. By default the job will not be monitored.

basename is the base name of the files to be assigned to the job. The default base name is `diana` (in the current working directory). The base name is valid for all files for the DIANA job. However, it may be overruled for the input, command or FILOS file:

file`.dat` default *basename*`.dat`is the name of the input file.

file`.dcf` default *basename*`.dcf`. is the name of the command file.

file`.ff` is the name of the FILOS file. DIANA takes the default name from the environment symbol `FF`. If this symbol is not set then the FILOS file will be `diana.ff`.

In some cases you may specify a file name via a `FILE=` parameter in the command file. If you do so, this name overrules the name in the run command.

If DIANA needs a file that it can't find, then it prompts for it when it runs in the foreground. For instance:

```
diana: <name.dcf> doesn't exist
command file:
```

and you have the opportunity to type the file name behind the prompt. If it runs in the background then the job will be aborted.

B.1.3 Error Messages

If you enter any incorrect information, or if DIANA encounters any other erroneous situation, an error message will be written to the standard output file. Two types of errors, with a different lay out, may be produced by DIANA's Error Message utility: *syntax errors* caused by syntactically incorrect commands or input data and *run-time errors* encountered during the analysis process.

B.1.3.1 Syntax Errors

Syntax errors may occur during reading and interpreting ('scanning') of the user commands or input data file. The error message consists of some lines of text with a question mark indicating the location of the erroneous word. For instance like in the following examples.

Command error *file*`.out`

```
Unexpected input CAUCHY
CAUCHY
Last line was
 FORCE CAUCHY
 FORCE ?
```

Input data error *file*.out

```
SCAN ERROR:
    2: 1    EMOD    2.0E11
    2: 1    EMOD ?  2.0E11
```

The consequence of a syntax error may be of two natures, in either case you should correct the error and re-run the job.

- If a syntax error is detected in a command file, DIANA stops interpreting the commands, the job will be aborted immediately.
- If a syntax error is detected in an input file, DIANA will, as far as possible, continue reading the input to detect other errors. The job will be aborted after the input file has been scanned, the analysis will not be performed.

B.1.3.2 Run-time Errors

During the analysis job, many types of errors can occur as a result of a wrong command order or of errors in the finite element model. These type of errors are called 'run-time' errors. The run-time error message will be written to the standard output file; the text is self-explanatory by nature, the DIANA User's Manual does not include a *List of error codes* or something like that. The text contains four types of information: an error code, the severity, a reference and the actual text of the message.

Error code. This code has an administrative meaning only. It indicates the Module/Segment in which the error was encountered and a number.

Severity. The severity of the error may be one of the following.

`ABORT` for very serious errors, the job will be aborted immediately.

`FATAL` if the error is serious. The job will be continued until the end of the current segment and then it will be aborted.

`WARNING` when DIANA can proceed the analysis normally. The user should assess the severity of the error and decide whether the results are reliable or not.

Reference, usually a reference to the DIANA User's Manual, to indicate the user where to look for the solution to the error.

Message text, often including hints on how to remove the cause of the error.

We will now discuss an example of a run-time error message, produced if a job is run with the commands:

file.dcf

```
*FILOS
INITIA
*INPUT
*LINSTA
BEGIN MODEL
 ASSEMB OFF
END MODEL
BEGIN OUTPUT
 DISPLA
END OUTPUT
*END
```

The error message is:

file.out

```
 /DIANA/AP/LS41    16:37:02      0.14-CPU     0.15-IO      99.-FA   BEGIN
 SEVERITY  : ABORT
 ERROR CODE: /DIANA/LS/EM40/0002
 ERRORMSG.A: Can't create element matrices: elements not assembled
 Use command-block *LINSTA/ASSEMB to assemble elements
 DIANA-JOB ABORTED
```

This error was encountered in Segment `LS/EM40` the error number is `0002`. The job will be `ABORT`ed immediately. The creation of element stiffness matrices was impossible due to the lack of element transformation matrices, resulting from the element assembling task by Module LINSTA. The assembling task was erroneously switched 'off', it must now be switched 'on'. The job could be restarted with the commands:

file.dcf

```
*LINSTA
BEGIN MODEL
 ASSEMB
END MODEL
BEGIN OUTPUT
 DISPLA
END OUTPUT
*END
```

If an error message occurs during the analysis, the severity of the error determines whether and if so, where, the DIANA *job will be aborted. The cause of the error determines where the analysis could be restarted.*

B.1.3.3 Other Error Messages

In rare cases it may occur that the computer's operating system produces messages on the system file like:

```
Division by zero
Square root of negative number
Floating point overflow
Disk full
CPU time limit
```

Fortunately, most of these errors will be intercepted by DIANA's Error Message utility and neatly reported in texts comprehensible to the user.

B.1.4 Job Logging

During the execution of a job, DIANA writes log information to the standard output file. This information consist of a listing of the DIANA segments which have been used in the job and a brief explanation about what they have done. For example, the following command.

file.dcf

```
*LINSTA
SOLVE
```

could produce the following log information on the standard output file:

file.out

```
 /DIANA/AP/LS41    16:37:02      0.14-CPU     0.15-IO      99.-FA   BEGIN
      SPARSE: DIM=128 NNZ(MAT)=872 NNZ(LU)=872
      DECOMPOSITION EXECUTED: DIM=128 SD=1.93e+01 HD=8.59e+02
      SOLVE: REDUCTION RES=0.18E-15 (INIT. RES=0.57E+03) NI=    1
```

The lines starting with `/DIANA` indicate the name and version of the segment, followed by the clock time and the CPU and I/O time used up to that moment. The latter is a measure for the data transport to and from the FILOS file. In the example, `/DIANA/AP/LS41` stands for the 'Application Linear Static – version 41'. The time is 16 hours 37 minutes and 02 seconds; 0.14 seconds of CPU time, 0.15 seconds of I/O time, and 99 accesses in the FILOS file had been used at the moment of the beginning of the segment. Each segment line can be followed by one or more lines with information on what the segment has done and what were the most important data. In the example, the segment has used the sparse solver; the dimension of the matrix was 128, indicated by parameter `DIM=128`; the number of non-zero terms for both the system matrix as for the lower-upper factorization was 872, indicated by the parameters `NNZ(MAT)=872` and `NNZ(MAT)=872`; solving the systems of equations was done in one iteration, indicated by parameter `NI=1`. Table B.1 on the next page summarizes the most important parameters in alphabetical order. In addition to parameters,

Table B.1: LOG LINE PARAMETERS

Parameter	Description
DIM=	Dimension of matrix.
HD=	Greatest diagonal term.
LU	Lower-upper factorization.
MAT	Matrix.
MC=	Highest number of load set.
ML=	Number of loadings (combinations).
MT=	Number of different basis types.
NC=	Number of iterations for creep.
ND=	Number of degrees of freedom.
NE=	Number of negative eigenvalues.
NI=	Number of iterations.
NL=	Number of nodal loads.
NNZ=	Number of non-zero matrix elements.
NQ=	Number of equations.
NS=	Number of iterations in the plastic algorithm.
NT=	Number of tyings.
NV=	Number of (load, displacement) vectors.
RES	Residual.
SD=	Smallest diagonal term.
TC=	Tolerance for crack criterion.
TD=	Angle for development of a new crack.
TO=	Tolerance for creep criterion.
TY=	Tolerance for yield criterion.

a segment sometimes includes information on the storage in the FILOS file like `SF.`*`name`*, this is only of importance for users who are carrying out research using DIANA, and it is not discussed here.

B.1.5 Running Under UNIX

This section describes how to use DIANA on a computer under the operating system UNIX. The reader is assumed to have a basic knowledge of UNIX. Many books have been written on the UNIX operating system, for instance by Bourne [3] and by Kernighan & Pike [7]. For DIANA users the following topics are of importance.

Logging in and out. Before you can use DIANA, a special shell program should be executed; that can best be done by means of the login file, for instance `.login` in the C shell. Consult your systems manager for this.

The structure of the file system and the commands to help you find your way within the UNIX system: `cd`, `pwd`, `ls`, `du`, `mkdir`.

The use of an editor, preferably a screen editor like `vi`, though any convenient text editor program may be used.

Some simple shell commands, primarily to manipulate files: `cp`, `mv`, `cat`, `lpr`, `pr`, `rm`, `chmod`.

The use of shell variables, for instance `setenv` in the C shell.

The use of utilities, mainly to look at files and/or to search within them: `more`, `tail`, `grep` etc.

Processes: starting a process; foreground and background. Process management by means of the commands: `ps`, `kill`, `nice`, `nohup`.

The help facility: the `man` command.

B.1.5.1 Files

As indicated in § B.1.2 on page 98, file names for DIANA jobs may be specified as arguments in the run command. For some files there is an alternative via the `FILE=` parameter in the command file. The FILOS file may also be specified via an environment symbol in UNIX terms called 'shell variable'. DIANA assumes default names if a file is not specified at all.

Protection. In order to protect existing files against being overwritten, DIANA adds the process identification number ***pid*** to the default names of the standard output and system file.

Linked files. At the end of the DIANA run, the regular file names `diana.out` and `diana.sys` will be linked to the standard output and system file respectively.

> *The result of simultaneously running jobs on the same directory is unpredictable with respect to the linked file names.*

The next example shows the situation of the default standard output file, called `diana.out`.

```
diana test.dcf test.dat ↩[1]
...
ls -l diana*.out ↩
5-rw-rw-r--  2 fcdw         4311 Nov 11 16:35 diana.out
5-rw-rw-r--  2 fcdw         4311 Nov 11 16:35 diana26663.out
```

[1] The symbol ↩ indicates that you press the key marked ↩, RETURN, or ENTER.

One file with two names, the second name containing the process identification number. A subsequent job, with a default output file name, first 'removes' the file `diana.out` but the file `diana26663.out` will exist until explicitly removed by the user.

B.1.5.2 Running in Foreground

On a UNIX system, a DIANA job is started as a foreground process by pressing the RETURN key immediately after the `diana` run command [§ B.1.2 p. 98]. The job is immediately started with high priority and the terminal will be blocked for other work.

- DIANA will prompt for necessary names of input or command file. The dialogue is like this:

  `diana` ↩
  `input file:` *`file`*`.dat` ↩
  `command file:` *`file`*`.dcf` ↩

  Once the job is finished, the prompt of the UNIX shell will reappear on the screen. If Module INPUT is not activated in the command file, no input will be read so there is no need to specify the name of the input file: the RETURN key may be pressed immediately.

- The system file is not created, all system information will be written to the terminal directly. In UNIX terms: 'standard error' is connected to `/dev/tty`.

- The terminal will be blocked so you can't continue to work while DIANA is running. In addition, the computer system is heavily loaded because the priority for foreground processes is high. Therefore, it is often better to run DIANA in background.

B.1.5.3 Running in Background

On UNIX, a process will run in background if an ampersand '`&`' terminates the command line:

syntax

`diana` [*`files`*] `&`

- In background it is impossible to prompt for file names, hence input and command files must be specified explicitly or the default files must be present.

- You may keep an eye on, or steer the process by means of UNIX commands like `ps`, `nice`, and `kill`.

- DIANA will ignore the monitor flag `-m` when running in background: no monitoring will take place [§ B.1.2 p. 98].

B.1.5.4 Submitting a Batch Job

On some UNIX systems it is possible to submit commands (scripts) in a batch queue for sequential background processing. Since this is not a standard UNIX facility, the use of batch processing for DIANA jobs cannot be presented here formally. Consult your local systems manager or UNIX manuals for a utility `submit`, `batch` or something like that.

B.1.6 Running Under MS-Windows

DIANA-9.3 for MS-Windows runs via the Graphical User Interface ¡DIANA [Ch. 2]. At installation time a shortcut to ¡DIANA has been created on your desktop.

Appendix C

Available Element Types

This appendix is an alphabetically ordered list of all elements available in DIANA. See Volume *Element Library* for a comprehensive description of these elements, including input data and background theory.

B2AGW Axisymmetric groundwater flow, boundary line, 2 nodes, linear.

B2AHT Axisymmetric potential flow, boundary line, 2 nodes, linear.

B2GW Groundwater flow, boundary line, 2 nodes, linear.

B2HT Potential flow, boundary line, 2 nodes, linear.

BC3AG Axisymmetric groundwater flow, boundary line, 3 nodes, quadratic.

BC3AHT Axisymmetric potential flow, boundary line, 3 nodes, quadratic.

BC3GW Groundwater flow, boundary line, 3 nodes, quadratic.

BC3HT Potential flow, boundary line, 3 nodes, quadratic.

BCL6S2 Fluid–structure line interface, 5 nodes, quadratic-linear.

BCL6S3 Fluid–structure line interface, 6 nodes, quadratic.

BCQ8GW Groundwater flow, boundary quadrilateral, 8 nodes, quadratic.

BCQ8HT Potential flow, boundary quadrilateral, 8 nodes, quadratic.

BCT6GW Groundwater flow, boundary triangle, 6 nodes, quadratic.

BCT6HT Potential flow, boundary triangle, 6 nodes, quadratic.

BQ24S4 Fluid–structure quadrilateral interface, 12 nodes, quadratic-linear.

BQ24S8 Fluid–structure quadrilateral interface, 16 nodes, quadratic.

BQ4GW Groundwater flow, boundary quadrilateral, 4 nodes, linear.

BQ4HT Potential flow, boundary quadrilateral, 4 nodes, linear.

BT18S3 Fluid–structure triangular interface, 9 nodes, quadratic-linear.

BT18S6 Fluid–structure triangular interface, 12 nodes, quadratic.

BT3GW Groundwater flow, boundary triangle, 3 nodes, linear.

BT3HT Potential flow, boundary triangle, 3 nodes, linear.

CHX20G Groundwater flow, 3-D, brick, 20 nodes, quadratic.

CHX20H Potential flow, 3-D, brick, 20 nodes, quadratic.

CHX60 Solid brick, 20 nodes, quadratic.

CHX64 Solid brick, 20 nodes, quadratic, hyperelastic.

CHX96 Solid brick, 32 nodes, cubic.

CL10T Curved truss bar, 2-D, 5 nodes, quartic.

CL12B Curved beam, 2-D, 4 nodes, degenerated cubic.

CL12I Line interface, 2-D, 6 nodes,

quadratic.

CL12T Curved truss bar, 3-D, 4 nodes, cubic.

CL15B Curved beam, 2-D, 5 nodes, degenerated quartic.

CL15T Curved truss bar, 3-D, 5 nodes, quartic.

CL18B Curved beam, 3 nodes, 3-D, quadratic.

CL18I Curved line interface, 6 nodes, quadratic, line–solid connection.

CL20I Curved line interface, 10 nodes, quartic.

CL24B Curved beam, 4 nodes, 3-D, cubic.

CL24I Line interface, to shell, 6 nodes, quadratic.

CL30B Curved beam, 5 nodes, 3-D, quartic.

CL32I Line interface, to shell, 8 nodes, cubic.

CL3CR Crack tip, 3-D, 3 nodes.

CL6CT Line contact interface, 2-D, 3 nodes.

CL6TB Line bounding, 3 nodes, quadratic, 2-D.

CL6TR Curved truss bar, 2-D, 3 nodes, quadratic.

CL8TR Curved truss bar, 2-D, 4 nodes, cubic.

CL9AX Axisymmetric shell, 3 nodes, quadratic.

CL9BE Curved beam, 3 nodes, 2-D, quadratic.

CL9PE Infinite plane strain shell, 3 nodes, quadratic.

CL9TR Curved truss bar, 3-D, 3 nodes, quadratic.

CQ12C Quadrilateral base for composed solid, 12 nodes.

CQ16A Quadrilateral axisymmetric, 8 nodes, quadratic.

CQ16E Quadrilateral plane strain, 8 nodes, quadratic.

CQ16M Quadrilateral plane stress, 8 nodes, quadratic.

CQ16O Quadrilateral plane stress, 8 nodes, quadratic, orthotropic.

CQ18M Quadrilateral plane stress, 9 nodes, quadratic, Lagrange.

CQ20A Quadrilateral axisymmetric, 8 nodes, quadratic, hyperelastic.

CQ20E Quadrilateral plane strain, 8 nodes, quadratic, hyperelastic.

CQ22A Quadrilateral axisymmetric, 9 nodes, quadratic, hyperelastic.

CQ22E Quadrilateral plane strain, 9 nodes, quadratic, hyperelastic.

CQ24C Quadrilateral contact interface, 3-D, 8 nodes.

CQ24GE Quadrilateral complete plane strain, 8 nodes, quadratic.

CQ24P Quadrilateral plate bending, 8 nodes, quadratic, Mindlin.

CQ24T Quadrilateral bounding, 8 nodes, quadratic, 3-D.

CQ36GE Quadrilateral complete plane strain, 12 nodes, cubic.

CQ36T Quadrilateral bounding, 12 nodes, cubic, 3-D.

CQ40F Quadrilateral flat shell, 8 nodes, quadratic, Mindlin.

CQ40L Quadrilateral curved shell, 8 nodes, quadratic, layered.

CQ40S Quadrilateral curved shell, 8 nodes, quadratic.

CQ48F Quadrilateral flat shell, 8 nodes, quadratic, Mindlin + ϕ_z d.o.f.

CQ48I Quadrilateral interface, 3-D, 16 nodes, quadratic.

CQ60S Quadrilateral curved shell, 12 nodes, cubic.

CQ8AG Axisymmetric groundwater flow, quadrilateral, 8 nodes, quadratic.

CQ8AHT Axisymmetric potential flow, quadrilateral, 8 nodes, quadratic.

CQ8CM Quadrilateral base for composed solid, 8 nodes.

CQ8GW Groundwater flow, quadrilateral, 8 nodes, quadratic.

CQ8HT Potential flow, quadrilateral, 8 nodes, quadratic.

CQ8KD Layered groundwater flow, quadrilateral, 8 nodes, quadratic.

CQ8RE Reynolds flow, quadrilateral, 8 nodes, quadratic.

CQ8TO Cross-section torsion, quadrilateral, 8 nodes, quadratic.

CT12A Triangular axisymmetric, 6 nodes, quadratic.

CT12E Triangular plane strain, 6 nodes, quadratic.

CT12M Triangular plane stress, 6 nodes, quadratic.

CT12O Triangular plane stress, 6 nodes, quadratic, orthotropic.

CT18C Triangular contact interface, 3-D, 6 nodes.

CT18GE Triangular complete plane strain, 6 nodes, quadratic.

CT18P Triangular plate bending, 6 nodes, quadratic, Mindlin.

CT18T Triangular bounding, 6 nodes, quadratic, 3-D.

CT27GE Triangular complete plane strain, 9 nodes, cubic.

CT27T Triangular bounding, 9 nodes, cubic, 3-D.

CT30A Triangular axisymmetric, 15 nodes, quartic, Lagrange.

CT30E Triangular plane strain, 15 nodes, quartic, Lagrange, hyperelastic.

CT30F Triangular flat shell, 6 nodes, quadratic, Mindlin.

CT30L Triangular curved shell, 6 nodes, quadratic, layered.

CT30S Triangular curved shell, 6 nodes, quadratic.

CT36F Triangular flat shell, 6 nodes, quadratic, Mindlin + ϕ_z d.o.f.

CT36I Triangular interface, 3-D, 12 nodes, quadratic.

CT45S Triangular curved shell, 9 nodes, cubic.

CT6AG Axisymmetric groundwater flow, triangle, 6 nodes, quadratic.

CT6AHT Axisymmetric potential flow, triangle, 6 nodes, quadratic.

CT6CM Triangular base for composed solid, 6 nodes.

CT6GW Groundwater flow, triangle, 6 nodes, quadratic.

CT6HT Potential flow, triangle, 6 nodes, quadratic.

CT6KD Layered groundwater flow, triangle, 6 nodes, quadratic.

CT6RE Reynolds flow, triangle, 6 nodes, quadratic.

CT6TO Cross-section torsion, triangle, 6 nodes, quadratic.

CT9CM Triangular base for composed solid, 9 nodes.

CTE10G Groundwater flow, 3-D, pyramid, 10 nodes, quadratic.

CTE10H Potential flow, 3-D, pyramid, 10 nodes, quadratic.

CTE30 Solid pyramid, 10 nodes, quadratic.

CTE48 Solid pyramid, 16 nodes, cubic.

CTP15G Groundwater flow, 3-D, wedge, 15 nodes, quadratic.

CTP15H Potential flow, 3-D, triangular prism (wedge), 15 nodes, quadratic.

CTP45 Solid wedge, 15 nodes, quadratic.

CTP72 Solid wedge, 24 nodes, cubic.

HX24L Solid brick, 8 nodes, linear.

HX25L Solid brick, 8 nodes, linear, hyperelastic.

HX8GW Groundwater flow, 3-D, brick, 8 nodes, linear.

HX8HT Potential flow, 3-D, brick, 8 nodes, linear.

ICL6H Potential flow, line interface, 6 nodes, quadratic.

ICQ16H Potential flow, quadrilateral interface, 16 nodes, quadratic.

ICT12H Potential flow, triangular interface, 12 nodes, quadratic.

IL4HT Potential flow, line interface, 4 nodes, linear.

IPT2H Potential flow, point interface, 2 nodes.

IQ8HT Potential flow, quadrilateral interface, 8 nodes, linear.

IT6HT Potential flow, triangular interface, 6 nodes, malinear.

L12BE Bending beam, 2 nodes, 3-D, Timoshenko or Bernoulli.

L13BE Bending beam, 2 nodes, 3-D, isoparametric.

L16IF Line interface, to shell, 4 nodes, linear.

L20IF Line interface, to shell, 3+2 nodes, quadratic/linear.

L2HT Cooling pipe, 2 nodes, linear.

L2TRU Truss bar, 1-D, 2 nodes.

L4CT Line contact interface, 2-D, 2 nodes.

L4HT Cooling pipe, 4 nodes, linear, nonsymmetric.

L4TB Line bounding, 2 nodes, linear, 2-D.

L4TRU Truss bar, 2 nodes, 2-D geometrically nonlinear.

L6BEN Bending beam, 2 nodes, 2-D, Timoshenko or Bernoulli.

L6TRU Truss bar, 2 nodes, 3-D geometrically nonlinear.

L7BEN Bending beam, 2 nodes, 2-D, isoparametric.

L8IF Line interface, 2-D, 4 nodes, linear.

N4IF Node interface, 2-D, 2 nodes, linear.

N6IF Node interface, 3-D, 2 nodes, linear.

PT1CR Crack tip, 2-D, 1 node.

PT3RO Point mass, rotation, 1 node.

PT3T Point mass, translation, 1 node.

Q12CT Quadrilateral contact interface, 3-D, 4 nodes.

Q12ME Quadrilateral plane stress, 4 nodes, linear, drilling d.o.f.

Q12PL Quadrilateral plate bending, 4 nodes, linear, Mindlin.

Q12TB Quadrilateral bounding, 4 nodes, linear, 3-D.

Q20SF Quadrilateral flat shell, 4 nodes, linear, Mindlin.

Q20SH Quadrilateral curved shell, 4 nodes, linear.

Q24IF Quadrilateral interface, 3-D, 8 nodes, linear.

Q24SF Quadrilateral flat shell, 4 nodes, linear, Mindlin + ϕ_z d.o.f.

Q48SPL Rectangular spline (strip), 8 nodes, 3 sections.

Q4AGW Axisymmetric groundwater flow, quadrilateral, 4 nodes, linear.

Q4AHT Axisymmetric potential flow, quadrilateral, 4 nodes, linear.

Q4CMP Quadrilateral base for composed solid, 4 nodes.

Q4GW Groundwater flow, quadrilateral, 4 nodes, linear.

Q4HT Potential flow, quadrilateral, 4 nodes, linear.

Q4KD Layered groundwater flow, quadrilateral, 4 nodes, linear.

Q4RE Reynolds flow, quadrilateral, 4 nodes, linear.

Q4TO Cross-section torsion, quadrilateral, 4 nodes, linear.

Q56SPL Rectangular spline (strip), 10 nodes, 4 sections.

Q8AXI Quadrilateral axisymmetric, 4 nodes, linear.

Q8EPS Quadrilateral plane strain, 4 nodes, linear.

Q8MEM Quadrilateral plane stress, 4 nodes, linear.

Q8OME Quadrilateral plane stress, 4 nodes, linear, orthotropic geometry.

SP12BA Base spring, 2 nodes, 3-D.

SP1RO Rotation spring/dashpot, 1 node.

SP1TR Translation spring/dashpot, 1 node.

SP2RO Rotation spring/dashpot, 2 nodes.

SP2TR Translation spring/dashpot, 2 nodes.

SP6BA Base spring, 2 nodes, 2-D.

T15SF Triangular flat shell, 3 nodes, linear, Mindlin.

T15SH Triangular curved shell, 3 nodes, linear.

T18IF Triangular interface, 3-D, 6 nodes, linear.

T18SF Triangular flat shell, 3 nodes, linear, Mindlin + ϕ_z d.o.f.

T3AGW Axisymmetric groundwater flow, triangle, 3 nodes, linear.

T3AHT Axisymmetric potential flow, triangle, 3 nodes, linear.

T3CMP Triangular base for composed solid, 3 nodes.

T3GW Groundwater flow, triangle, 3 nodes, linear.

T3HT Potential flow, triangle, 3 nodes, linear.

T3KD Layered groundwater flow, triangle, 3 nodes, linear.

T3RE Reynolds flow, triangle, 3 nodes, linear.

T3TO Cross-section torsion, triangle, 3 nodes, linear.

T6AXI Triangular axisymmetric, 3 nodes, linear.

T6EPS Triangular plane strain, 3 nodes, linear.

T6MEM Triangular plane stress, 3 nodes, linear.

T6OME Triangular plane stress, 3 nodes, linear, orthotropic geometry.

T9CT Triangular contact interface, 3-D, 3 nodes.

T9MEM Triangular plane stress, 3 nodes, linear, drilling d.o.f.

T9PLA Triangular plate bending, 3 nodes, linear, Kirchhoff.

T9TB Triangular bounding, 3 nodes, linear, 3-D.

T9WME Triangular plane stress, 3 nodes, nonlinear wrinkling.

TE12L Solid pyramid, 4 nodes, linear.

TE4GW Groundwater flow, 3-D, pyramid, 4 nodes, linear.

TE4HT Potential flow, 3-D, pyramid, 4 nodes, linear.

TP18L Solid wedge, 6 nodes, linear.

TP6GW Groundwater flow, 3-D, wedge, 6 nodes, linear.

TP6HT Potential flow, 3-D, wedge, 6 nodes, linear.

Appendix D

Background Information

D.1 Organization around DIANA

In this section we will briefly discuss the organization of development, marketing, and user-support of the DIANA finite element code, as schematically shown in Figure D.1. DIANA is owned by the Dutch TNO organization, where the TNO

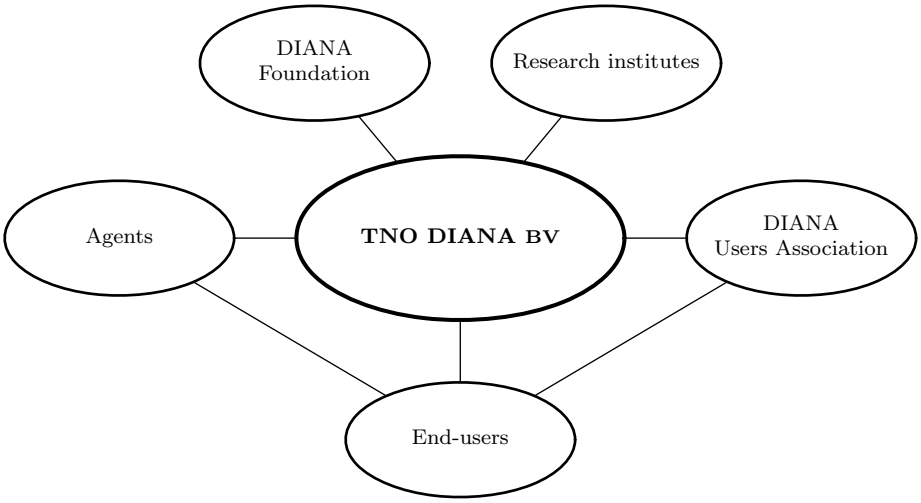


Figure D.1: DIANA organization

DIANA BV is responsible for the development, maintenance, support and sales of the code. In order to provide a good first-line support and to assure an active relation with users all over the world, TNO DIANA BV has appointed agents in different parts of the world. In their regions, these agents manage the sales, marketing, promotion and first-line support with respect to DIANA. In some

regions agents organize user-meetings on a regular basis, where information on DIANA or its applications is exchanged. For those regions where no agent has been appointed, the sales, marketing, promotion and first-line support is provided by TNO DIANA BV. The DIANA Users Association[1] serves as an independent platform for exchange of user's experiences. This association also indicates requirements for new developments toward TNO DIANA BV.

D.2 Reporting a Problem

To prepare problem reports, a program `disysinfo` is delivered with the DIANA-9.3 release. Running this executable outputs the machine information and the appropriate DIANA version. You are requested to send problem reports by e-mail to your DIANA support organization. Please notice the following checklist for e-mailing problem reports.

- Please add the output of `disysinfo`.
- Please indicate the type of the problem report: software defect, documentation error, change-request, or a support problem.
- Please describe your problem as clearly as possible and state all facts.
- Please specify how to reproduce the problem. Please send us all your `.dat` and `.dcf` files (in strictest confidence if you wish). Note that a problem is hard to fix if we can't reproduce it.
- If you know a work-around for the problem please specify.
- To achieve a unique reference, please send only one problem per problem report.

D.3 Quality Assurance

The DIANA Test Suite is a comprehensive set of finite element tests to verify the correctness and consistency of the DIANA code. Tests are classified with keywords. The same keywords are used to classify examples as described in Volume *Analysis Examples*. DIANA-9.3 comes with a utility program `dtest_w`, an interactive tool which enables you to find all tests which contain a set of specified keywords. To start the utility you must click the Dtest icon in the DIANA Start folder (MS Windows) or type the program name `dtest_w` on the command line (UNIX): Now the Diana Test Selection window pops up on your screen [Fig. D.2]. If you click the Help button at the bottom, `dtest_w` displays a summary of the functionality which we will describe in more detail below. In the Test Selection dialog window you may recognize two boxes:

[1] In Dutch: 'DIANA Ontwikkelingsvereniging' abbreviated as 'D.O.V.'.

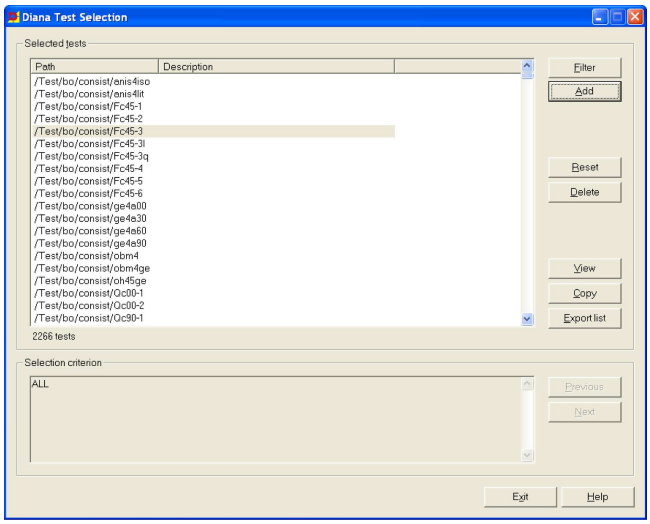


Figure D.2: Test Selection window

Selected Tests is a list box which displays the current list of tests: the pathname optionally followed by a descriptive title. Initially this list contains all the tests in the Test Suite. As there are over 1600 tests, a slide rule on the right edge enables you to browse through the list. You may delete tests from the list or add tests to the list via the Delete, View, and Copy buttons (see below).

Selection Criterion is a read-only box which shows the current selection criterion. The Previous and Next buttons respectively reset the current criterion to the previous or to the next one.

On the right of the window there are seven buttons. If a button activates a sub window, then a Help button will give you more information on its functionality. The Delete, View, and Copy buttons become active only if you select one or more tests in the list box. You may do so by clicking and dragging with the left mouse button.[2] The functionality of the various buttons is as follows.

Filter only list tests which comprise a set of indicated keywords.

Add add tests, which comprise a set of indicated keywords, from the complete list to the current list

Reset reset the list of tests to the complete list, i.e., all tests in the Test Suite.

Delete delete the selected tests from the current list.

[2]Selected tests will be highlighted.

View show the input data file, the command file, or the keywords of the selected test(s).

Copy copy the input data and command file of the selected test(s) to a user directory.

Export list write the current list of tests to a text file.

To leave the dialog you must click the Exit button at the bottom.

D.4 Historical Notes

For those interested, this section gives a brief summary of the history of the DIANA code.[3]

Birth. In succession to the development of a special purpose finite element
1970 program for linear analysis of orthogonal structures, named COLOS, in the early seventies of the twentieth century, TNO Building and Construction Re-
1972⋆ search[4] originated the development of the DIANA finite element code in 1972. Initially, the idea was to develop an in-house code for consultancy work in the field of concrete mechanics and civil engineering. As the code was based on the displacement method, it was called DIANA which is an acronym for DIsplacement ANAlyzer. At that time the computer facilities consisted of a remote terminal for submission of punched card jobs to a CDC-6600 main frame com-
1974 puter. The primal version of DIANA was running in 1974. The source code comprised about ten thousand punched cards, stored in five strong steel boxes.

First analyses. The young DIANA was a tool for the analysis of real structures and TNO was lucky to obtain contracts for the analysis of some complex off-
1975 shore structures in 1975. It turned out that software development and structural analysis required a lot of computer jobs and that the bottleneck for progress was the remote computer service. To perform the modeling of the structure and interpretation of the analysis results, the need for mesh generation, and plotting facilities became obvious. Furthermore, particularly for the analysis of large reinforced concrete structures, it would be desirable to include nonlinear phenomena such as cracking of concrete and plastic deformation of steel. To cope with all these problems and requirements, in-house computing facilities were urgently needed.

[3] This section is a compilation of two articles by De Witte [4] and Kusters [8] on the occasion of the 25th anniversary of DIANA in 1997. It is also based on Chapter 1 of the Annual Review 1994 of the DIANA Foundation.

[4] At that time called TNO-IBBC.

In-house use. In 1975 TNO-IBBC purchased its first mini-computer: a Harris/4 with about 48 Kb of core-memory and 2×10 Mb of disk space. It was chosen because of its 24-bit architecture, which yielded more accurate analysis results than the popular 16-bit PDP-11/45 of Digital Equipment Corporation. However, because of the lack of memory, many programming 'tricks' had to be used to get a feasible implementation. One of these tricks was the development of the file and memory management system FILOS which, in modified form, still 1976
serves as a special database management system for DIANA. To facilitate the creation and checking of the finite element model, two new modules were developed: MESH for automatic mesh generation and GRAPHI to display the model and its analysis results. Both modules came available in 1977, and were used 1977
to analyze parts of the 'Oosterschelde Deltawerken' in Zeeland. At that time, DIANA's reinforcement modeling option was a unique feature, not available in competitive finite element codes.

Developing advanced analysis methods. Having the Harris computer in-house, the turn-around time of analysis and development jobs decreased dramatically. Moreover, new sponsors became interested in TNO's R&D activities: the Dutch MATS and CUR research funding organizations. The CUR organized a large Concrete Mechanics project which lasted until 1990 and was carried out in cooperation with the Technical Universities of Delft and Eindhoven and with the Dutch Ministry of Transport and Public Works.

Both the in-house computing facility and the research funding enabled the development and implementation of more advanced analysis methods, which resulted in the first working versions for nonlinear and dynamic analysis around 1978. DIANA's first brochure tells all about the facilities at that time: for in- 1978
stance three-dimensional analysis of concrete structures, including crack analysis and plastic deformation of embedded steel reinforcement.

External use. In 1979 the Harris computer was replaced by a more powerful and accurate machine: a 32-bit VAX-11/780 of Digital Equipment Corporation, 1979
running the VAX/VMS operating system. Also at that time, the first version of the DIANA User's Manual was completed, still in Dutch and printed on a line printer. DIANA had now grown to about 200.000 statements and gradually, the attractiveness of the code was also recognized by engineering offices and researchers outside TNO. For this reason, the first professional executable product version of DIANA was prepared. The DIANA-1 release was delivered to the Dutch Ministry of Transport and Public Works in the Hague in 1980, to 1980
run on a UNIVAC-1108 main frame computer.

Entering the market. A VAX-11/780 at that time cost somewhat more than half a million Dutch guilders ($\approx$ US $ 200.000), which was more than small engineering consultant companies could afford. TNO did realize that, to enter the market with application software for structural analysis, it would be essential to have it running on low-cost computers. However the personal computer in

those days was not sufficiently powerful for an application like Finite Element Analysis.

Fortunately, there was an R&D project going on at TNO to develop a low cost, but powerful micro computer for Computer Aided Design applications:
1981 the GEMINIX, based on the Motorola MC-68000 processor and probably the world's first micro computer running the UNIX operating system. DIANA was successfully ported to the GEMINIX and in 1983 this combination was installed
1983 at three customer sites: two engineering consultant companies and the Public Works department of Rotterdam.

A growing users community. As their number increased significantly, the external users wished to organize themselves. This led to the establishment
1984 of the DIANA Users Association in 1984, a platform for exchange of user's experience, which also indicates priorities for new developments toward TNO.
1988 This led to the DIANA-2.0 release in 1988, with new modules for potential flow analysis, and for connection to external pre- and postprocessors. The 2.0 release came with a user's manual and a user's course and text book, now all in English which allowed DIANA to go international. The first customer outside The Netherlands was the University of Darmstadt in Germany.

In the late eighties, the research community discovered DIANA's potential as a software development environment in addition to its service for end-use. TNO's major partners asked for access to the source code and the associated programmer's toolkit to establish their own developments in DIANA. This marked
1989 the birth of the DIANA Foundation on May 9, 1989, a joint initiative of universities, research institutes and industrial partners. The role of TNO was, and is, to transfer these developments to the product version of DIANA, including quality assurance, documentation and maintenance, to achieve continuity of the developments. Since January 1991 the Foundation has been recognized and approved by the Netherlands Organization for Scientific Research (NWO) as Expertise Center for Computational Mechanics.

Marketing and support for new releases. In order to provide high quality maintenance and development of DIANA, TNO appointed DIANA Analysis
1990 BV in 1990 to manage sales, marketing, promotion, and first-line support of DIANA. The 3.2 release was the first one to be distributed and supported by DIANA Analysis BV. It came with new modules for fracture mechanics, dynamic response, and stability analysis. The element library was extended with flat shell and interface elements, and with elements for groundwater flow analy-
1991 sis. DIANA-4.1 was released about one year later. Significant extensions in this release were an iterative solver, phased analysis, indirect displacement control in nonlinear analysis, and a new family of orthotropic membrane elements.

The members of the DIANA Foundation asked for more information about the DIANA programming environment. Therefore TNO developed a program-
1992 mers course, which was given for the first time in 1992. The programming environment was supported primarily on powerful workstations under UNIX.

However, the power of personal computers had increased to such an extend that the user's community asked for a port to the MS-DOS operating system. This was established in 1993 with the DIANA-5.1 release. Important additions to 1993
the analysis features in this release were a substructuring technique in the solution procedure, stability analysis with imperfections, nonlinear analysis control improved with arc-length and automatic load control, and new modules for parameter estimation, and pipeline analysis. The element library was extended with higher order elements for various families and with layered elements.

Getting mature. In the mid-nineties, the DIANA user community had grown to such an extend that it became about time for the "First international DIANA conference on computational mechanics" [9], jointly organized by DIANA 1994
Analysis BV, the DIANA Foundation, the DIANA Users Association, and TNO. The next release was DIANA-6.1 in 1996, with improved meshing facilities, an 1996
iterative solution method optimized for vector and parallel computers, the analysis of wind and water wave load, a line search algorithm for nonlinear analysis, nonlinear dynamics, postbuckling, and contact analysis. New material models for clay and concrete were added, as well as models for viscoplasticity and viscoelasticity. The new user-supplied subroutine option supported a general material model of particular interest for R&D sites.

With respect to postprocessing, the 6.1 release brought facilities to determine and plot influence lines and to make contour plots. The external pre- and postprocessor FEMGV was coupled to DIANA to provide for an interactive graphics interface, including general meshing and color plots of analysis results.

Twenty five years and onward. On the occasion of DIANA's twenty fifth birthday, the "Second International DIANA Conference on Computational Mechanics" [5] was held in June 1997. As DIANA was, and still is, characterized 1997
by two key-words: research and end-use, the conference brought together researchers and end-users engaged in finite element modeling, and new developments in computational mechanics. The titles of the various sessions indicate DIANA's wide variety of applications: "Concrete mechanics and concrete structures," "Geomechanics and soil–structure interaction," "Steel and composite structures," "Computational mechanics of materials," and "Finite element technology and software development."

In 1998 DIANA-7.1 was released. An important improvement was the en- 1998
hanced DIANA environment for the FEMGV-5.2 pre- and postprocessors. Another new feature in the user-interface was the on-line version of the user's manual, to be used via a web-browser. The 7.1 release offered new material models for concrete cracking and crushing, an option to simulate corrosion of reinforcement steel, a module for mobile load analysis, and extended options for geotechnical analysis. As of the 7.1 release, DIANA also supported the MS-Windows platform for PC's.

DIANA-7.2 was released as an upgrade to 7.1 in 1999, now combined with 1999

FemGV-6.1 with many enhancements for interactive graphics pre- and post-processing and a fully integrated on-line user's manual. Another important enhancement was the availability of new constitutive models, particularly suited to analyze the liquefaction of saturated soil due to earthquakes. Together with Diana-7.2 TNO introduced a new product called 'Micro-Diana'. For the benefit of a reduced license fee, Micro-Diana has all the analysis capabilities of the mother program but allows a limited number of nodes in the finite element model.

The new millennium. In the first year of the new millennium the development of two major product lines was initiated: (1) the complete integration of Diana and FemGV, resulting in the general purpose graphical interactive environment ¡Diana in version 8, and (2) special purpose versions of Diana with dedicated graphical user interfaces for specific applications.

2000

Shell International Exploration and Production bv commissioned TNO to develop special versions of Diana for their private usage. The choice for the two product lines required a restructuring of the code such that components with clear tasks are identified which can easily be combined in new applications. In parallel Femsys Ltd. was ordered to extend FemGV with specific functions for Diana, such as reinforcement preprocessing, hierarchical property forms, menu configuration on selected model types, visualization of cracks etc. The year 2000 was world-wide a very successful year for new sales as the number of licenses increased with 40%.

2001 In the year 2001 the first results of the research project '4D-Computing' came available in the development version in the form of two new solvers: Sparse Cholesky and ILU-preconditioning. This project aimed on speeding-up Diana and was supported by the D.O.V. In the same year Diana-2D was introduced, a special version for the analysis of two-dimensional models.

2002 The first major release of the new millennium was introduced in 2002 as Diana-8.1. It came with a fully integrated pre- and postprocessing environment ¡Diana, derived from FemGV-6, and a graphical interactive control of analysis commands. New material models came available particularly suited for analysis of soil and concrete like Delft Soft Soil, Hoek–Brown, and Rankine Hill anisotropic. Also added were models for young hardening concrete. Among the new analysis capabilities were a module for spectral response analysis and the new solvers.

In October 2002 the "Third Diana World Conference" took place in Tokyo [6]. By this time, Japan had become the most important export market for Diana. The emphasis of the conference was on application of advanced computational models in civil engineering applications.

A new organization for DIANA. In 2002 TNO prepared a new organization around Diana: a company named TNO DIANA bv was founded and in the beginning of 2003 all technical activities were transformed from TNO Building and Construction research to the new company. Also the marketing

2003

and sales activities, until then being done by DIANA Analysis BV, were transferred to TNO DIANA BV. At the same time TNO DIANA BV became owner of Femsys Ltd. Thus a new organization had been created in which commercial and technical activities were integrated with the purpose to direct services in an optimal way to DIANA users world-wide.

In May 2003 the Second edition of release 8.1 was made available. In this version the remaining applications, such as Fracture Mechanics Analysis and Beam Cross-section Analysis, were included in the graphical user interface. Also some new line interface elements for shells were introduced.

2004 At the end of 2004 DIANA-9 was introduced. This version offered a completely new interactive Graphical User Interface. Various analysis functions were also added. For instance new automatic nonlinear solution procedures, complete plane strain elements, and improved options for geotechnical analysis.

2005 Early 2005 the DIANA product suite was enhanced with a graphical mesh editor which can visualize DIANA finite element models, as defined via an input data file or translated from a NASTRAN model.

At the end of 2005 TNO DIANA BV and MIDAS IT announced that they had entered into a strategic alliance.

2007 Early 2007 DIANA-9.2 was released as an upgrade to DIANA-9. This was the first DIANA version suited for the combined use of the midas FX^+ for DIANA pre- and postprocessor and DIANA.

Bibliography

[1] Adobe Systems Inc. *PostScript Language Reference Manual*. Addison Wesley, 1989.

[2] Bathe, K.-J. *Finite Element Procedures in Engineering Analysis*. Prentice-Hall, 1982.

[3] Bourne, S. R. *The UNIX System*. Addison-Wesley, 1982.

[4] de Witte, F. C. DIANA's birth and childhood. *Diana World*, 1 (1997), 9–11.

[5] Hendriks, M. A. N., Jongedijk, H., Rots, J. G., and van Spanje, W. J. E., Eds. *Finite Elements in Engineering and Science – Proc. 2nd Int. DIANA Conference on Computational Mechanics* (1997), Balkema.

[6] Hendriks, M. A. N., and Rots, J. G., Eds. *Finite Elements in Civil Engineering Applications – Proc. 3rd DIANA World Conference* (2002), Balkema.

[7] Kernighan, B. W., and Pike, R. *The UNIX Programming Environment*. Prentice-Hall, 1984.

[8] Kusters, G. M. A. DIANA getting mature. *Diana World*, 2 (1997), 14–15.

[9] Kusters, G. M. A., and Hendriks, M. A. N., Eds. *DIANA Computational Mechanics '94 – Proc. 1st Int. DIANA Conference on Computational Mechanics* (1994), Kluwer.

[10] NAFEMS. *Guidelines to Finite Element Practice*. National Agency for Finite Element Methods & Standards (NAFEMS), Glasgow, 1984.

[11] NAFEMS. *A Finite Element Primer*. National Agency for Finite Element Methods & Standards (NAFEMS), Glasgow, 1992.

[12] Shreiner, D., Ed. *OpenGL Reference Manual: The Official Reference Document to OpenGL*, 3rd ed. No. ISBN: 0201657651. Addison Wesley, 1999.

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Page numbers. Bold face numbers indicate pages with formal information about the entry, e.g., a syntax description (**36**). Italic numbers point to an instructive example of how the concept in question might be used (*132*). Underlined numbers refer to theoretical backgrounds on the subject (95).

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